HELSINKI SCHOOL OF ECONOMICS (HSE)
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DETERMINANTS OF PORTFOLIO DIVERSIFICATION IN U.S. VENTURE CAPITAL AND PRIVATE EQUITY FUNDS

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Sami Kivisaari
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Tarkastajat:
KTT, Sami Torstila
KTT, Vesa Puttonen

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ABSTRACT
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Objectives The study examines the determining factors of U.S. based venture capital and buyout fund portfolio diversification. The types of diversification investigated cover simple diversification based on number of portfolio companies, diversification based on portfolio company industries and financing stages, and time based diversification. Also tendency of funds to syndicate is studied. The primary objective is to find out what are the main determinants of different types of portfolio concentration.

Data The data obtained from Thomson VentureXpert database covers over 70000 distinct financing rounds through 1965-2007 by U.S. based venture capital and private equity funds in portfolio companies.

Results The results show that increase in supply of private equity capital tends to decrease concentration of venture capital funds and increase the time it takes for the funds to invest their capital. On the other hand, the results show that increase in demand of venture capital through increased research and development (R&D) spending will work the opposite way. Increased R&D spending will also increase tendency of venture capital funds to co-invest with other funds.

Venture capital fund investment time decreases with fund manager experience. First time funds tend to be more diversified in terms of number of portfolio companies than follow-on funds, which indicates that first time funds may be diversifying in attempt to avoid large failures and to secure their chances of raising follow on fund.

In addition, the results show that corporate venturing funds tend to be more concentrated in terms of portfolio company industries than independent venture capital funds. Funds associated with financial corporations and investment banks tend to be more diversified and consist of more companies than other fund types.

Concentration and diversification of venture capital funds tends to be sensitive to many different macroeconomic variables such as bond yields, stock market returns, GDP development, and overall capital committed to asset class. For buyout funds, there are no significant results to report.

Keywords Venture capital, buyout, private equity, diversification, specialization, concentration, syndication

HELSINGIN KAUPPAKORKEAKOULU
Pro-gradu tutkielma / Rahoitus
Sami Kivisaari

TIIVISTELMÄ
9.5.2008

YHDYSVALTALAISTEN PÄÄOMASIJOITUSRAHASTOJEN SIJOITUSSALKKUJEN HAJAUTUSASTEEN MÄÄRITTÄVÄT TEKIJÄT

Tavoitteet Tutkielma pyrkii selvittämään yhdysvaltalaisten pääomasijoitusrahastojen salkkujen keskittymiseen ja hajautumiseen vaikuttavia tekijöitä. Keskittymisen ja hajaantumisen lajit jotka ovat tutkimuksen kohteena sisältävät salkussa olevien yritysten lukumäärän, toimialoihin ja kehitysvaiheisiin perustuvan hajauttamisen, kehitysvaiheeseen sekä ajallisen hajauttamisen. Lisäksi rahastojen taipumus syndikoituihin sijoituksiin on tutkimuksen kohteena.

Aineisto Thomson VentureXpert tietokannasta saatu aineisto sisältää yli 70000 erillistä yhdysvaltalaisten pääomasijoitusrahastojen rahoituskierrosta aikaväliltä 1965-2007

Tulokset Tulokset osoittavat että pääoman tarjonnan lisääntyminen pyrkii vähentämään venture capital rahastojen keskittymistä ja kasvattamaan pääoman sijoitukseen kuluvaa aikaa. Toisaalta tulokset osoittavat että tutkimus- ja kehitysinvestoinneista lähtöisin oleva pääoman kysynnän lisääntyminen pyrkii vaikuttamaan päinvastaiseen suuntaan. Lisäksi T&K lähtöinen pääoman kysynnän lisäys pyrkii kasvattamaan venture capital rahastojen taipumusta syndikoituihin sijoituksiin.

Venture capital rahastojen pääoman sijoittamiseen kuluva aika pyrkii vähenemään rahaston hallinnoijan kokemuksen myötä. Uudet rahastot pyrkivät olemaan hajaantuneempia kohdeyritysten määrällä mitattuna kuin jatkorahastot, mikä osoittaa että uudet rahastot saattavat hajauttaa sijoituksiaan pyrkiäkseen välttämään suuria epäonnistumisia ja varmistamaan mahdollisuutensa jatkorahastojen keräämiseen.

Tulokset osoittavat lisäksi että corporate venturing rahastot tapaavat olla salkun yritysten toimialoilla mitattuna keskittyneempiä kuin riippumattomat venture capital rahastot. Rahastot jotka ovat liitoksissa rahoituslaitoksiin tai investointipankkeihin pyrkivät olemaan hajaantuneempia kuin riippumattomat venture capital rahastot ja sisältämään suuremman määrän kohdeyrityksiä.

Venture capital rahastojen keskittyminen ja hajaantuminen näyttää olevan herkkä useille makrotaloudellisille muuttujille kuten yritysjoukkolainojen tuotoille, julkisten osakemarkkinoiden tuotolle, BKT:n kehitykselle ja pääomasijoitusrahastoihin allokoidun pääoman määrään. Buyout-rahastojen osalta tutkimus ei anna aihetta merkittäviin johtopäätöksiin.

Avainsanat Pääomasijoittaminen, hajautus, keskittyminen, syndikointi

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1 Introduction

1.1 Background and Motivation

During the past twenty five years, private equity as an asset class has experienced a tremendous growth in size. According to Private Equity Intelligence, as reported by Financial Times in 6th July 2006, investors have allocated more than $1,3 trillion globally for investments in private equity funds. Reported by Venture Economics, more than 9000 funds have raised in excess of $1,9 trillion from institutional and other investors. The capital raised has primarily been used in financing buyouts and venture capital investments. In its article 25th November 2004, The Economist dubbed private equity funds as the new kings of capitalism. With largest fund sizes exceeding over $15 billion, liberal use of leverage, and relative freedom from regulation, private equity funds are nowadays significant active players in the financial market with ability to tackle buyout deals of nearly any size. The inflows to venture capital funds provide financing for innovative growth companies and generate new growth business which may be seen beneficial to society at large.

Venture capital and private equity have been studied from several different perspectives: fund returns (Kaplan and Schoar 2003, Phalippou and Gottschalg 2007, Ljungqvist and Richardson 2003), investment project returns (Cochrane 2005), pricing of undiversifiable risk (Jones and Rhodes-Kropf 2003), syndication and co-investment between different funds (Lerner 1994, Manigart 2002), fund investment patterns Ljungqvist and Richardson (2003), structure of venture capital funds (Sahlman 1990), determinants of fund size (Willert 2008), return differences between diversification and specialization strategies (Tenenbaum 1993, Knill 2005, Lossen 2006). Gupta and Sapienza (1992) study the industry diversity and geographic scope preferences of venture capital funds with sample of 169 U.S. venture capital funds located in states of California, Massachusetts and Texas. Surprisingly, however, there does not seem to be many other studies that investigate the determinants of diversification and specialization of venture capital and private equity funds as dependent variable using a comprehensive sample.

The foundations of modern portfolio theory are based on the basic idea that diversifying investor's portfolio across multiple investment targets whose returns are less than perfectly

correlated with each other will allow the investor to reduce risk while retaining the expected return, thus increasing the risk adjusted return (Markowitz 1952). From portfolio theory perspective investment targets can be modeled as random variables with known expected return and variance. When expected return and variance are known, the selection of optimal portfolio with maximum risk adjusted return reduces to a simple mathematical optimization problem. Portfolio theoretic optimal portfolio for investor is a combination of market portfolio and risk free asset, the exact combination depending on investor risk aversion. It could be then argued that from portfolio theory point of view, more diversification is always better.

When investors are passive and atomistic with respect to investment targets, and perfect information is available, portfolio theory makes sense. However, when this is not the case, other arguments become relevant. At least two different alternate lines of theory focus on advantages of specialization over diversification and can be seen to run contrary to the portfolio theoretic approach.

First, in private equity world where investors acquire significant stakes of their portfolio companies and practice active ownership, the investors can add value to their portfolio companies in several ways. For example, in venture capital sector competent and well connected investors can help recruiting senior officers (Gorman and Sahlman 1989, Hellman and Puri 2002), striking strategic alliances (Stuart, Hoang, and Hybels 1999), assembling additional funds and achieving liquidity by hiring investment bankers (Barry et al. 1990, Megginson and Weiss 1991), locating M&A partners (Gans, Hsu, and Stern 2002), and certifying initial public offerings (Megginson and Weiss 1991) and M&A deals. Similarly, buyout fund managers may effect changes in corporate strategy, operating model, structure, and corporate governance that result in incremental shareholder value compared to passive equity investment.

Second, there are theories that stress the costs of asymmetric information and specialization as a way to lower these costs. Costs of asymmetric information generally arise through the basic concepts of moral hazard and adverse selection. The availability of low quality deals for fund managers is generally higher than the availability of high quality deals. Differentiating between the two requires expertise that can be achieved through specialization and experience. In this way, better ability to select deals leads to lower costs of adverse selection. Moral hazard may occur when entrepreneurs that have received venture capital financing choose to pursue strategies

that yield high personal benefits for entrepreneurs but low expected financial return for venture capitalists, or alternatively when in absence of significant downside risk entrepreneurs choose to pursue high risk strategies that maximize their expected return. Such limited downside and unlimited upside risk is similar to call option on company assets (Lossen 2006). Value of this kind of position increases with volatility favoring risk seeking behavior. Specialization and experience may be helpful in structuring optimal incentive structures that minimize costs of moral hazard to outside investor.

As there are at least two main lines of theory about relative benefits of diversification and specialization, it makes an interesting point to study which are the main determinants of fund diversification. Further knowledge in this area should allow further testing of the diversification and specialization hypotheses. There are also several aspects regarding fund specialization and diversification that have not been thoroughly discussed. For example, the connection between diversification and specialization, and fund performance may not be simply unidirectional as the risk aversion of fund managers is also affected by their previous success. Wealthy and established private equity firms operate more funds and can afford to take larger risks in their funds than younger and smaller firms (Jones and Rhodes-Kropf 2003). Therefore, it is appropriate to ask whether these funds are more specialized? First time funds need to signal their quality to potential investors (Gompers and Lerner 1994) in order to raise follow-on funds so should we expect that there are diversification differences between first time and follow on funds? Do diversification practices of funds backed by non-financial corporations and commercial and investment banks differ from non-affiliated funds? Does tendency to syndicate and co-invest also imply high degree of diversification? The list could go on, but it should be obvious that further research on the subject would certainly add value. Diversification is also of interest for limited partners that need to assess the total risks of their portfolios, and regulators that oversee investing of pension funds that are also major investors in private equity.

1.2 Research problem and objectives

This primary objective of this study is to investigate the observable determinants of U.S. based venture capital and private equity fund portfolio concentration and diversification. The types of diversification that this study addresses are diversification based on portfolio company industries,

diversification based on portfolio company financing stages, time based diversification, and number of portfolio companies. Also, related issue of investment syndication or tendency of funds to co-invest with other funds is studied. Since I have not been able to find an existing study that investigates exactly this dimension of venture capital and private equity funds, there is no natural point of departure from which to continue posing specific questions and hypotheses. Therefore, the first objective is the basic quantification of different concentration measures for different classes of funds and explorative determination of factors that are most significant in explaining the observed concentration measures.

In addition to basic quantification, a set of hypotheses are derived based on existing research on venture capital and private equity funds. Most of existing research focuses on different aspects of risk and return characteristics of funds and their determinants. The hypotheses are derived primarily from these findings to investigate whether the same determinants also affect observed portfolio diversity.

The primary research questions posed based on existing work are as follows:

- Are there differences in portfolio concentration between first time funds and follow-on funds?
- Does fund manager experience and reputation imply differences in portfolio concentration?
- Does supply and demand of private equity capital affect the realized concentration of fund portfolios?
- Does fund affiliation imply differences in fund portfolio concentration? For example, are there differences between independent partnerships, corporate venturing subsidiaries, and funds affiliated with financial corporations and investment banks?
- To what extent the determining factors of portfolio diversification are equivalent between venture capital and buyout funds and what are the main differences?

These questions are further elaborated in the literature study part and the section focusing on development of testable hypotheses.

1.3 Contribution of the thesis

This thesis contributes to existing research in several ways. First of all, private equity fund portfolio diversity and determining factors of portfolio diversity have received surprisingly little attention in venture capital and private equity literature. I have not been able to find an existing study that comprehensively addresses the exact topic this thesis focuses on. There are, however, several other studies that address issues closely related to fund diversity, which I will briefly review in this section. In this respect, this study complements the existing research on the subject. Second, my study examines a large data set through a long time period (1965-2007) covering all financing rounds of U.S. based venture capital and private equity funds with over $10 million of funds under management recorded by Thomson VentureXpert. Comprehensiveness of the data should increase significance of the results. Third, portfolio diversity is studied from multiple different viewpoints using different metrics, providing a more holistic view that focusing only on one or two metrics alone would provide.

One aspect from which diversification and specialization has been previously studied is as strategies and determinants of fund returns. Jones and Rhodes-Kropf (2003) show that better ability to diversify decreases the residual undiversifiable risk that fund managers must bear and may increase competitive advantage of the fund. Lossen (2006) studies fund industry diversity, stage diversity, time diversity, country diversity, and number of portfolio companies as explainers of fund returns and finds that rate of return decreases with stage diversification and increases with industry diversification. Knill (2004) examines performance differences in diversification versus pure-play strategies in venture capital and finds that neither strategy optimizes both venture capital growth and time to entrepreneurial exit. Also, Norton and Tenenbaum (1993) study specialization and diversification as venture capital investment strategies.

Second, less studied area, is which kind of funds tend to diversify and which tend to specialize instead. Gupta and Sapienza (1992) study fund diversity preferences of U.S. based venture capital firms located in California, Texas, and Massachusetts focusing on industry diversity and geographic diversity preferences. As said, their study only focuses on investment preferences and not the actual observed portfolio diversity.

1.4 Scope of the thesis

The funds studied in this thesis are all U.S. based venture capital or buyout funds. U.S. based means that both the private equity firm and the fund are domiciled in some of the U.S. states. Foreign investments of U.S. based funds are included in the sample but these investments cover only quite small portion of the total amount invested. Funds smaller than 10 million dollars of capital under managed are excluded from the scope of research mainly to keep the amount of data manageable and also to avoid certain potentially problematic issues with very small funds. Excluded were also funds of funds, mezzanine capital funds, and certain specialty funds such as energy and real estate funds.

The thesis does not aim to explain the implications of higher or lower degree of fund diversification but rather aims to explain which types of funds tend to diversify and which types of funds tend to specialize instead. Also, the thesis generally does not assume that all observed differences in fund concentration are necessarily conscious choices of fund managers to control fund risk profile, control costs of asymmetric information, or to obtain complementary resources or information. Rather, observed differences could simply reflect differences in for example the business environment the funds operate in.

1.5 Structure of the thesis

This first chapter presents background information along with motivation, the research problem, the contribution of the thesis, and the scope and structure of the thesis. The second chapter drills down to the subject by outlining the general characteristics of private equity funds and private equity industry. The chapter continues with a more detailed literature review that surveys the earlier studies about venture capital and private equity funds, and their characteristics.

The third chapter focuses on developing testable hypotheses which are utilized in the empirical part of the study. These hypotheses are primarily based on the literature study part. Chapter four presents the data set used, variables of interest, concentration measures, and also describes the relevant research methodology. Chapter five reports the results of the study with detailed discussion about findings. Chapter six wraps up the findings and presents the conclusions that were reached based on the results of the empirical study. Finally, references are presented in chapter seven.

2 Theoretical background

2.1 Private equity funds and industry

2.1.1 Industry overview

European Venture Capital Association (EVCA) defines private equity investing broadly as investing in securities through a negotiated process. This definition may be overly broad but it both implies that the investment process is distinct from the process of investing in securities of public corporations, in which little if none negotiation is usually necessary, and also that private equity investing covers more than investing only in equity instruments. Indeed, the amount of negotiation and due diligence required in average private equity deal is considerable and the private equity deals may cover a wide array of different financing structures involving common stock, convertible preferred stock, convertible debt, subordinated debt with warrants attached and others. Private equity investments are typically intermediated, that is, the ultimate investor generally invest in the asset class through funds rather than directly. The primary reasons are that average deal sizes are large, lumpy, and illiquid making diversification and exit difficult. Another reason is that managing the investments to target companies needs specialized know-how that is not widely available.

As the name implies, private equity funds mainly deal with non-public companies either by directly investing in unlisted companies or financing going private deals in which public corporations or parts of them are taken private. Although the funds mainly deal with private companies, some funds also invest in listed corporations through private investment in public equity (PIPE) deals. PIPE deals typically occur with public corporations that seek equity capital in times when public offering would not be able to raise funds at reasonable terms due to either firm condition or general stock market sentiment. Private equity investors are generally active investors in that they actively take part in governance of target companies through monitoring, advice, hiring key managers, and board representation.

There are many kinds of funds. The major components of the industry are venture capital funds, and buyout funds. Smaller but significant components are mezzanine capital funds, special

situations funds, and funds of funds. Funds of funds invest in other funds rather than directly and may or may not have focus in one of the main categories.

Venture capital involves investing in new growth companies that may or may not be profitable at the time of investment. Venture capital is generally further divided by the stage of investment targets to pre-seed, seed, startup, expansion, and replacement capital. Venture capitalists seek to invest in companies that are expected to grow fast and have the potential of well above average returns. Venture capital investments are high risk and can be seen to fulfill a financing gap that young firms in many industries, such as high-technology, software and biotechnology industries, with high up-front product development costs and uncertain future cash flows face. For these types of companies, other sources of financing may be limited as small size, lack of operating history, and lack of profitability excludes retained earnings and conventional debt financing from the available possibilities. Venture capitalists specialize in carrying the risk and are willing to invest in these companies, provided that returns are attractive enough to compensate for the risk. However, it is not only the ability and willingness to bear risk that sets venture capitalists apart. Successful venture capitalists have managerial backgrounds in growth companies similar that they are financing and are able to create value by utilizing their experience and contacts while participating in governance of the portfolio companies.

Buyout funds typically target acquisitions of significant portions or controlling ownerships of more mature companies with well established business plans. The buyout fund investments may be aimed at financing expansions, consolidations, and turnarounds, as well as sales or spinouts of divisions and subsidiaries of larger corporations. As the investment targets of buyout funds are generally much more stable and established than the investment targets of venture capital funds, buyout funds typically use high degrees of leverage to boost the returns on investment. Recently, buyout funds have faced competition from direction of hedge funds in large capitalization deals (Judd 2006) as some hedge funds have adopted the active owner approach that is characteristic to private equity. While distinction between the hedge funds and buyout funds may in some cases be blurred, hedge funds typically focus in public companies, whereas private equity buyout funds mostly specialize in less liquid private companies.

Mezzanine capital funds typically invest in target companies through debt or debt-like instruments such as subordinated or preferred debt, paired with equity kickers such as warrants attached that provide upside potential in addition to the steady income streams that the debt instruments produce. Mezzanine capital derives its name from the fact that it is senior to equity but junior to other debt holders.

Special situations funds, or event driven funds, invest more broadly and specialize in taking advantage of one time events that provide an opportunity to make a tactical profit. These opportunities could include investing in debt securities of distressed companies, one-time opportunities arising from changes in industry trend or government regulations, as well as project finance.

The private equity funds differ in whose money they are investing. Independent private equity partnerships are most common and raise bulk of their capital from outside investors separately each time they raise a new fund. So called captive funds are different in that they mainly invest capital of their parent organizations. Typically, captive funds are venture or buyout subsidiaries of investment banks or other financial corporations. Corporate venturing constitutes another noteworthy class of captive funds in which non-financial corporation invests in smaller growth companies typically with the intent of making better use of its own resources and gaining access to new ideas, new research and development, and more entrepreneurial culture. Many large technology corporations such as Sun Microsystems, Intel, Cisco, and Xerox have run or are currently running their own corporate venturing programs as an alternative approach to internal R&D. Captive funds pose some research problems as the amount of capital actually committed in them is not as straightforward to find out than in the case of independent private equity partnerships, complicating, for example, return on investment calculations.

2.1.2 Organization and lifecycle of private equity funds

Until the 1980s, the predominant legal form of private equity funds was a closed end investment trust or a small business investment corporation (SBIC). Nowadays, most private equity funds are organized as limited partnerships in which the private equity company represents the general partner and the fund investors represent the limited partners. The general partner assumes the responsibility of managing the fund and the limited partners supply most of the investment

capital to the fund. The capital invested by general partners is small and accounts usually on the order of one percent of total committed capital (Sahlman 1990). As limited partners, the investors are only liable for the capital they invest while the general partner has unlimited liability for all the funds commitments. The lifetime of the partnership is generally limited to average of about ten years (Sahlman 1990) with an option to extend the fund life by about two to three provided that this is required by market conditions. One reason for the prevalence of limited partnership form of organization is taxes. As the limited partnership is not a taxable entity in itself, tax exempt investors such as endowment funds gain because the fund profits are not taxed at fund level. To be eligible for this pass-through tax treatment, the partnerships need to meet several criteria. For example: the fund life must be limited and the termination date agreed-upon, the transfer of limited partnership units must be restricted (i.e. not easily bought and sold), withdrawal from partnership before termination must be prohibited, and that limited partners may not take active part in management of the partnership (Sahlman 1990).

The lifecycle of a private equity fund can be seen as series of stages. The main stages are raising the fund, screening of targets, investing, post-investment monitoring, exit, and returning capital. The first stage is raising the fund. This involves marketing the fund to potential investors and getting commitments to invest in the fund. The fund raising phase could take months or even a year or two. The year when the fund was raised is generally referred to as the vintage year of the fund. Ability to raise funds is generally heavily dependent on past success and reputation of the fund managers. Due to importance of reputation, first time fund managers may have the incentive to take excessive risks or exit investments earlier than optimal, in an effort to create a reputation (Gompers 1996).

After sufficient amount of capital has been committed by the investors, the fund is ready to start making investments. This is referred to as initial closing. Some funds may accept more investments even when it has started making investments if certain conditions are met but generally the funds have a certain total capital target after which the fund undergoes final closing and is not open to further investments (Schell 1999). While in investing phase, general partners screen for deals, perform due diligence on promising investment candidates, negotiate deals, and make decisions to invest or not to invest. When investment is made, the fund managers will continue to monitor the company and take active part in its governance.

Investing behavior of venture capital funds and buyout funds differ from each other. Generally, venture capital investments in portfolio companies are staged. That is, the financing rounds are tied on accomplishment of predefined milestones where successful accomplishment will allow further rounds of financing. Investments are staged to control risk and asymmetric information problems between venture capitalist and the entrepreneur (Neher 1999). Buyout funds are different in that they typically make one large investment in the target company to obtain controlling ownership in company or buy out a division or subsidiary.

The funds do not usually take down all the committed capital at once. Instead, when the fund has identified an investment target, it calls the limited partners to transfer money into the fund account. This act of requesting capital from limited partners is referred to as capital call and is based on the earlier commitments made by limited partners. Failure to participate in capital call carries stiff penalty payments. It takes in average six years for funds to invest 90% of committed capital. In addition, funds do not necessarily invest all capital that has been committed in them (Ljungqvist and Richardson 2003).

The limited lifetime of private equity fund implies that the fund has to be able to make an exit from the portfolio companies. A typical exit time frame for private equity funds is in the order of four to five years and could be more or less. In any case, the exit time frame cannot exceed the life of fund. The excess returns of private equity funds realize late in their lifecycle. According to Ljungqvist and Richardson (2003), the internal rate of return (IRR) of funds turns from negative to zero in average of eight years from initial investment, and exceeds comparable public equity investment return in average of ten years.

The primary ways to exit an investment are initial public offering (IPO), trade-sale or an M&A deal, or write-off. The initial public offering is generally considered the most successful type of exit. In this case the portfolio company is taken public and the fund will end up with shares of publicly traded company that can either be sold or distributed directly to fund partners. A trade-sale or an M&A deal involves selling the portfolio company to either financial buyer such as another private equity fund or to a strategic buyer, that is, to a non-financial company that operates in the same or related industry as the portfolio company. Trade sale may result in either cash payment or shares in the acquiring firm. Write-off is the worst case scenario. In this case the portfolio company has not proved to be economically viable and is terminated either in

bankruptcy procedure or voluntary liquidation. The fund then realizes any residual value that might result from liquidation of firm assets after the payments to more senior claimholders. It is worth noting significant portion of investments ends up as "living dead" investments. These "zombie" investments are companies that end up being economically viable but only to marginal extent so that they are unable to produce adequate returns that are expected by venture capitalist. Treatment of these investments varies but often they are simply written off.

The income to fund and general partners generally consists of management fees and incentive payments. The management fee is supposed to cover the costs of running the fund, while the performance based payments are supposed to both align the fund manager interest with that of limited partners and provide the real compensation for fund managers. Management fee of about 2% of committed capital during investing period of the fund, and 2% of invested capital after the investment period has passed is a common arrangement. Incentive payments typically take the form of 20% carried interest from fund returns exceeding some predefined hurdle rate. (Gompers and Lerner 1999, Sahlman 1989) There are also funds whose business model is also based on fees charged to portfolio companies; however, these funds are quite rare. Most funds are primarily interested in pure return on investment.

2.1.3 Asymmetric information and contracting issues in venture capital

Asymmetric information and agency problems that arise from it are central issue in private equity investments, especially in venture capital. Divergent interests between the principal and the agent may impose significant costs for the principal if not accounted for. Agency problems generally rise from inability of principal to observe the actual actions taken by agent. Therefore, it is impossible to write perfect contract between the two, outlining the specific actions the agent must undertake for the principal. The agent may undertake actions that are unfavorable for the principal, or more often, fail to undertake action that is beneficial to principal but costly to the agent. The usual solution to the problem is to align the interests of principal and agent through incentive arrangements.

Two basic classes of problems arising from information asymmetries are adverse selection and moral hazard. Adverse selection is in play when it is more likely for less informed party to choose a bad alternative because he is unable to distinguish between the two. Moral hazard is the

case when the more informed party engages in harmful behavior because he is not carrying the full cost of the action.

In venture capital, problematic information asymmetries mainly occur at two levels: between the limited partners and the fund managers, and between the fund managers and the entrepreneurs seeking financing for their projects. As significant amount of fund managers wealth is tied in the portfolio they are managing, because limited partners generally are well diversified, and because the limited partners commit capital into the fund before investments are made and the limited partners cannot verify whether realized fund performance was affected by chance or fund managers actions, the fund managers may have incentive to invest in less risky projects than the principals would prefer. High degrees of carried interest compensation of fund managers can be seen as a measure to align the interests between limited partners and general partners.

Between fund managers and entrepreneurs, the main problem is adverse selection. There are far more bad investment project being offered to fund managers than there are good ones. This can be verified as approximately 5% of business plans submitted to venture capitalists eventually manage to obtain financing. This problem is generally countered by fund managers specializing in certain kinds of firms, by staging of investment rounds so that further funding is contingent on meeting pre-specified milestones, and by contractual provisions. There exist a large number of different contractual features that allocate cash flow rights, board rights, voting rights, liquidation rights, and other control rights mainly in the attempt to create proper incentive structure that primarily stem from issues of asymmetric information (Kaplan and Strömberg 2003).

2.1.4 Problematic issues in private equity research

There are several issues with private equity funds that complicate their research. The main problems arise from lack of mandatory reporting requirements, subjectivity of reporting, misleading accounting treatment, and selectivity of disclosures.

Private equity funds are generally free from excessive regulation and disclosure requirements as it is assumed that their investors are principally qualified institutional investors and wealthy individuals that are savvy enough to recognize and bear the risks in such investment. Because of that, in most jurisdictions, there are no special purpose laws governing private equity partnerships. Instead, the relevant statutes setting the disclosure requirements for private equity

funds are found in accounting law, and relevant company law governing limited partnerships. Depending on conditions, funds are generally under no obligation to publicly disclose their financial statements, composition of their portfolios, or details about their fee structures.

Most private equity funds belong to industry associations such as National Venture Capital Association (NVCA) in U.S., British Venture Capital Association (BVCA) in U.K., and Finnish Venture Capital Association (FVCA) in Finland. Most member companies confidentially report basic data such as portfolio compositions, capital commitments, and fund investments and exits to industry associations that based on the data publish aggregate information about industry to their members and to general public. Private equity research companies such as Thomson Venture Economics and DowJones VentureOne generally receive data from national and regional venture capital associations, annual fund reports from some private equity firms, and data from larger limited partners investing in private equity. They also gather information from publicly available sources such as financial media in digital and paper form. From this, the research companies are able to compile searchable databases that cover significant amount of private equity transactions that have taken place. Although the data collected by research companies covers substantial amount of global transactions and is double checked against several sources, it is does not solve all problems. Some data such as fund returns and cash flows is still confidential, and it is generally not possible to have access to this kind of data except in highly aggregated form. Some researches have managed to have access however.

Another issue is that there are no active markets for portfolio companies and the values of fund portfolio companies are subjective estimates at best. Pricing transactions are intermittent and practically occur only when there is a new financing round or when the portfolio company is sold or listed in stock exchange. Typical accounting treatment for fund investments is to capitalize investments at cost and only update the book value when there is a reliable pricing transaction than can be used to assign new value for the investment. Even if the value assigned is based on transaction in which real money changed hands, it is only valuation based on estimates of few parties. It is not at all guaranteed that portfolio company could actually be realized at the same value again. Obviously, valuation of private companies can never be as exact as with public companies.

There are also a number of potential biases that need to be controlled in research. First issue is the selection bias. For example, initial public offerings and large M&A transactions typically imply large positive returns to funds and are very likely to be noticed by private equity research companies and get recorded in databases. The fund managers also have incentives to make such events well publicized. However, smaller M&A transactions and company write offs typically imply negative returns and have smaller chance of being noticed thus introducing bias to the sample. Survivorship bias is another type of systematic error which can arise from the fact that managers of funds that do better than average are also more likely to raise follow on funds. Managers of funds whose performance is sub par may not be able to raise follow-on funds as previous fund performance is taken as a signal of fund manager quality. Finally, look-ahead bias may be involved in cases where the realization of ultimate event cannot be known at the time of study. For example, if number of fund portfolio companies were studied on funds that are still investing, then it would be likely that funds would invest in more companies after the sampling has taken place, which would introduce a negative look-ahead bias.

2.2 Characteristics of private equity funds

2.2.1 Fund risk and return

In their study of private equity fund returns Kaplan and Schoar (2003) make several findings about the patterns of private equity fund returns. Their sample, which is obtained from Venture Economics, covers the actual realized cash flows in and out of funds through the years 1980 to 2001. Kaplan and Schoar find that net-of-fees the value weighted returns of venture capital funds exceed the S&P500 returns and the returns of buyout funds fall short of S&P500 returns during the sample period. Equal weighted net-of-fees returns both under perform S&P500 index. Despite of this, the results suggest that gross-of-fees, both venture capital and buyout funds exceed the S&P500 returns. The sample of returns from different funds has considerable amount of dispersion as the cash flow internal rate of return for the 25th percentile of funds was 3% and for the 75th percentile 22%. Even more interesting than the actual returns of the funds is that Kaplan and Schoar document strong correlation between performances of subsequent funds raised by the same general partners. They control for industry and investment stage differences, risk differences, and positive performance biases but results are robust to these control factors. Kaplan

and Schoar also report that the fund performance increases with fund size and general partner's experience. The performance increase of the fund tends to attract more capital into the funds. However, unlike mutual funds for which the relationship between performance and capital inflow is convex, it is concave for private equity funds. Finally, Kaplan and Schoar find that funds started at boom times perform worse and are less likely to raise a follow-on fund.

Ljungqvist and Richardson (2003) study the actual realized cash flows in and out from venture capital and buyout funds with the purpose of characterizing the capital investment and return patterns of funds, determinants of the speed that funds invest their capital, the time period it takes for the investment in fund to become positive in returns, the risk profile of private equity funds in terms of systematic and unsystematic risk, and determining whether private equity investment returns are impressive taking into account their risk profile and different benchmarks. The study does not rely on the usual sources of data previously used in private equity return research such as VentureXpert and VentureOne databases. Instead the authors have gained access to proprietary dataset from the records of one of the largest institutional investors in private equity in U.S whose identity remains undisclosed. The study is significant because the data set is quite large, spans relatively long time period of 1981 to 2001, is completely free from selection biases, consists of actual realized cash flows instead of estimates and self-reported fund values, and reports some patterns previously unreported in literature. Ljungqvist and Richardson find that private equity has generated substantial excess returns over the period of their study, the internal rate of return net of fees being 19,81%, which indicates a 6% premium over investment in public equity market. Ljungqvist and Richardson also find that in average, it takes three and six years, respectively, to invest 56,9% and 90,5% of committed capital and over eight and 10 years, respectively, for fund IRRs to turn positive and eventually exceed public equity returns, respectively. In other words, it takes a very long time before the returns realize. Ljungqvist and Richardson suppose that at least part of the substantial observed excess returns on private equity investments might be premium for holding illiquid investment of ten years maturity.

Phalippou and Gottschalg (2007) study a dataset of 1328 mature private equity funds challenging many assumptions of previous research. They find out that gross-of-fees private equity funds outperform S&P500 by about 3% but net-of-fees underperform S&P500 by almost the same amount. Phalippou and Gottschalg argue that the residual values reported by mature funds near

the end of their life largely represent living dead investments. That is, their true value being significantly less than their book value, most probably near zero. In many earlier papers, these residual values have been simply treated as end of period positive cash flow of the size of reported residual value. Phalippou and Gottschalg argue that fund returns would be more truthfully reported by writing off these investments. Based on their sample, Phalippou and Gottschalg draw these conclusions because all the sample funds have reached typical liquidation age and in addition are either officially liquidated or have had no cash flows over the last six quarters, and because 71% of the residual values are reported by funds with neither cash flow activities for more than three years nor revision in residual values for more than three years. Treating residual values as zero reduces the fund returns measured with profitability index by 7%. Phalippou and Gottschalg also challenge the usual practice of weighting the private equity fund returns by the amount of committed capital. Committed capital might be inadequate weighting criterion because funds differ in the rate in which they invest their capital and the amount they invest in average (Ljungqvist and Richardsson 2003). Assuming that funds with lower performance invest their capital slower, the internal rate of return of such funds would be downward biased. Instead of committed capital, Phalippou and Gottschalg weigh fund performance by present value of investments and find that this choice reduces the average profitability index by 2%. There paper presents some other findings and also confirms the results of Kaplan and Schoar (2005) regarding fund performance persistence. The performance persistence is found out to actually subsume all the other fund characteristics in explaining performance.

Phalippou and Gottschalg conclude that private equity returns, in average, are not impressive and propose three additional motives for investing in private equity: learning, mispricing, and positive externalities. Learning hypothesis holds that investing in private equity requires skill and by participating in potentially poorly performing funds run by inexperienced managers, the limited partners are tacitly obtaining right to participate in future more profitable funds run by the same managers when they have become more experienced. The learning hypothesis is also suggested by Lerner, Schoar, and Wong (2007) who report large differences in returns for different types of limited partners. Another alternative is mispricing. The mispricing hypothesis states that certain investors might have misvalued the private equity asset class by attributing too much weight on few successful investments, or that the common way of reporting private equity returns gross-of-

fees is overstating the returns available to limited partners thus confusing some investors. Finally, the positive externalities hypothesis holds that investing in private equity funds may yield positive side benefits. This view holds that certain investors could be strategically investing in private equity funds simply in the purpose of establishing commercial relations with the fund managers. For example, buyout funds tend to use high degrees of leverage and banks could have incentive to invest in funds to promote their own lending business.

2.2.2 *Risk and return measured at investment project level*

A study by Cochrane (2001) is the one of the first studies that attempts to study the gross returns of venture capital investments, that is, returns from portfolio companies to the fund gross of fees and incentive payments. Cochrane acknowledges that there are serious sample selection issues because investments that are exited through IPO, trade-sale, or M&A can be readily observed but investments that are written down or that venture capitalist cannot exit in favorable terms but that still keep operating are less readily observed. This sample selection bias tends to exaggerate alpha and underestimate beta of gross returns unless taken into account. Cochrane models the probability distributions of the different fates of a portfolio company and using maximum likelihood method, estimates the sample selection parameters as well as alpha and beta for the gross returns. Cochrane finds out that the bias-corrected estimates neatly account for log-normal return distribution and that the bias corrected returns are significantly different from those without bias correction. With bias correction, the mean log return is reduced from 108% to 15% and the logarithmic market model intercept, which can be regarded as model alpha, is reduced from 92% to -7%. Regarding arithmetic returns, bias correction reduces mean arithmetic return from 698% to 59% and arithmetic alpha from 462% to 32%. Cochrane points out that, without bias correction, high volatility is significant driver of high arithmetic returns and that investments in venture companies have similar payoff profiles as call options. In the study, Cochrane also points out that small value NASDAQ stocks exhibit similar kind of behavior as investments in venture companies. The study used data set from the Venture One database.

Quigley and Woodward (2003) study venture capital industry as a whole and in their paper they derive a gross-of-fees return index for direct investments in venture capital companies. Their study uses unique data set from Sand Hill Econometrics to derive the index. In their study, similarly as Cochrane (2001), Quigley and Woodward recognize that there are serious sample

selection issues in building the index because valuation events are intermittent, and practically the only case in which the outcome of a valuation event is known for sure is when company carries out an initial public offering. As private companies, the portfolio companies are not under any obligations to disclose the transaction prices in case of new financing rounds, trade sale or M&A, or write down. The venture capital index is obtained using modern hybrid version of the repeat-sales technique that was originally introduced by Bailey, Muth and Nourse (1963) for measuring housing prices. Quigley and Woodward improve the model by compensating for sample selection bias using Heckman (1979) style sample selection model. With the help of venture capital index constructed, Quigley and Woodward characterize the risk and return of venture capital asset class. They find that the real returns to venture capital averaged more than 5%, which is substantially less than S&P500. Returns to NASDAQ index averaged 9,66%. They also find that venture capital is substantially more volatile than S&P500 and slightly more volatile than NASDAQ index. The estimated beta between venture deals and S&P500 is 0.07 and 0.30 between venture deals and the NASDAQ index. The estimated correlation between venture capital and S&P500, and venture capital and NASDAQ were 0.04 and 0.30, respectively. According to the study, at moderate risk levels of risk, an optimal portfolio should hold about 10-15% of venture capital. The portfolio allocation was derived using Markowitzian mean-variance optimization.

2.2.3 Supply and demand of private equity capital

One way to look at private equity market as whole is the standard supply and demand framework familiar from macroeconomics. In this framework, price can be seen as the expected rate on return of private equity investment and the quantity as total dollars invested in private equity. The supply schedule then denotes the venture capital investors', i.e. the limited partners', aggregate expected rate of return at each level of aggregate dollars invested in private equity. On the other hand, the demand schedule then denotes the maximum aggregate discount rate on private equity investment that the entrepreneurs are willing to accept at each level of aggregate dollars invested in private equity. The demand schedule is expected to slope downward as, in presence of any given amount of capital, the investment projects that offer the best return get financed first. In general, supply schedule should be upward sloping as greater expected returns attract more investors. However, since financial assets are primarily held for the monetary returns they return, and because under this assumption there is very large amount of substitutes with similar risk-

return characteristics in financial markets, the supply schedule should be nearly flat (Gompers and Lerner 1998). In demand-supply framework, ceteris paribus, increases in supply should decrease the equilibrium price and increases in demand should increase the equilibrium price.

Gompers and Lerner (1998) investigate which factors drive the supply and demand of venture capital and the flow of capital into the industry. Their sample consists of independent venture capital organizations from 1972 through 1994. Gompers and Lerner find that the 1979 U.S. Deparment of Labor's clarification of Employment Retirement Income Security Act (ERISA) "prudent man" rule, whose interpretation previously had effectively prevented the pension funds from investing in venture capital, had major impact on the subsequent exponential growth of venture capital industry in the U.S. They also find that there exists strong negative correlation between capital gains tax rate and the amount of venture capital raised. This could either be because at supply side lowered capital gains tax rate makes venture capital investments more attractive for taxable investors or alternatively at demand side lowered capital gains tax rate make it relatively more favorable for corporate managers to rather start their of growth businesses. This effect was first reported by Poterba (1989). Gompers and Lerner conclude that data seems to favor the demand side explanation. They also find that macroeconomic factors such as gross domestic product (GDP) growth and growth in research and development (R&D) are correlated with amount of funds raised. Like many other studies (e.g. Kaplan and Schoar 2003), Gompers and Lerner find that, at fund level, previous fund performance and reputation of the venture capital firm are positively correlated with the amount of capital raised. The fund data used in the study was from Venture Economics.

Another study by Gompers and Lerner (2000) finds that inflows of capital into the venture capital asset class have significant effect on the valuation of venture capital funds' new investments even after controlling for public equity market valuation and firm characteristics. In their study, the higher valuation of new investments was not found to be correlated with better success of the same firms. The evidence suggests that there is limited number of attractive deals that the capital committed to venture capital asset class must compete for. In other words, with increased competition, there may be too much money chasing too few deals. The higher inflows to private equity asset class should therefore result in increased deal competition between private equity

funds and drive up the valuations of portfolio investments. Higher valuations in turn should lead to lower returns.

The results of Gompers and Lerner are to some degree controversial to the financial theory. As the value of any security is defined as the discounted future cash flows yielded by the security and because this way defined, there always exist close substitutes to almost any given investment, the movement in deal valuations should be driven by expectations about future cash flows and opportunity cost of capital instead of supply and demand. In absence of perfect markets, Gompers and Lerner find evidence that the effect of demand may be explained by segmentation and disconnectedness of venture capital market. For example, venture funds generally are only allowed to do venture investments and many venture firms are local in their geographical reach. When there are many such venture firms, the range of substitute investments is limited and the funds' investment opportunity sets may be dramatically reduced by increased fund inflows and increased competition, thus driving the deal prices up.

2.2.4 *Fund manager reputation and certification hypothesis*

Hsu (2004) finds that in case of multiple competing bids from more than one venture capitalists, the entrepreneurs tend to not only pay attention to the financial terms of the deal but also to the reputation of the venture capitalists. In other words, from two competing venture capitalist financing proposals the entrepreneurs may choose a proposal that has a lower firm valuation than the competing bid if the differential value of venture capitalist contact exceeds the difference in relation to first-best financial valuation. Quantitatively, Hsu finds that venture capitalists with good reputations, acquire equity stakes in portfolio companies at 10% to 14% discount.

There are many ways in which well connected venture capitalists having strong expertise and track record may bring more value to the table than just the value of financing package. These include assisting in recruiting senior officers (Gorman and Sahlman (1989), Hellman and Puri (2002)), striking strategic alliances (Stuart, Hoang, and Hybels (1999)), and assembling additional funds and achieving liquidity by hiring investment bankers (Barry et al. (1990), Megginson and Weiss (1991)), or locating M&A partners (Gans, Hsu, and Stern (2002)). Another source of value for entrepreneurs is the certification of company quality provided by reputable

venture capitalist, which may render the company more attractive to business partners and other financiers.

Megginson and Weiss (1991) study the effect of venture capital affiliation in initial public offerings. They find that firms backed by reputable venture capitalists are able to attract higher quality underwriters and auditors, and that the venture backed initial public offerings in average have lower under pricing and lower underwriter fees than non venture backed initial public offerings. This effect is explained by certification. In other words, as initial public offering is not a one time only transaction for venture capitalist and the venture capitalist has reputation capital to protect, the incentives for venture capitalist to overstate the company value to equity markets are significantly lower than for the company itself or another venture capitalist with less reputation at stake. Megginson and Weiss also note that for venture capitalists, initial public offering is not generally a quick cash-out device but most venture capitalists hold their shares in target companies for extended period after the lock-up provisions expire.

2.2.5 *Diversification and asymmetric information*

There are several papers that have examined the effect of diversification on private equity fund returns (e.g. Jones and Rhodes-Kropf 2003, Lossen 2006). There are two mutually contradictory lines of theory whether diversification has positive or negative impact on risk adjusted fund returns. On the other hand, like in case of public equity, diversification is seen to reduce the idiosyncratic company specific risk and is thus seen as beneficial. However, on the other hand, investments in private companies are characterized by significant information asymmetries and principal agent conflicts (Amit, Brander, and Zott 1998, Chan 1983). To counter these problems, private equity firms tend to specialize in certain industries, funding stages, and other dimensions, thus reducing degree of diversification. Another, more subtle, issue is whether diversification has effect on net-of-fees or gross-of-fees basis.

Jones and Rhodes-Kropf (2003) study the venture capital and buyout fund returns at both portfolio company and fund levels using the principal-agent framework. They model the investment as a three stage process where the limited partners and general partners first negotiate investment contract, after which general partners scan for investment opportunities and make the investments in portfolio companies, and finally when returns from portfolio companies are

realized and proceeds paid to fund investors after fees and incentive payments. Participants of the model are the limited partners, the general partners and entrepreneurs.

In Jones and Rhodes-Kropf model, entrepreneurs do not have money and need general partners to invest in their companies to realize their projects. Most of entrepreneurs' wealth is tied in their companies and they are essentially undiversified. Limited partners in turn have money and are well diversified while general partners do not have significant amounts of money by themselves but their wealth is primarily determined by their investment performance based incentives. As single fund manager can only manage limited amount of companies, the general partners are only partially diversified. Information between participants is asymmetric as the contract between general and limited partners is negotiated before general partner learns the risk of the projects they invest in. Also, the limited partners are unable to observe the actions of general partners and are only able to observe the ex-post investment performance. As the general partners are incompletely diversified, they face an amount of residual idiosyncratic risk, which must be priced as there is no other market participant that is able to diversify the risk away. From the asymmetric information and differential risk characteristics of model participants Jones and Rhodes-Kropf expect that in competitive markets, returns to limited partners must exhibit zero alphas but returns to general partners will have positive alphas. The positive alpha is the compensation to general partners for bearing the undiversified residual nonsystematic risk.

Jones and Rhodes-Kropf find that the data supports predictions of their model. However, they also find that the funds with most idiosyncratic risk tend to exhibit abnormal returns, even for limited partners. The study also predicts that the key competitive advantage in private equity fund industry may not be just the ability to pick the best deals but rather the ability to manage many uncorrelated investment projects simultaneously. In this case the diversification benefits are seen to result in competitive advantage. Furthermore, the study argues that second source of competitive advantage is lower degree of risk aversion than the competitors have. Jones and Rhodes-Kropf use the risk aversion argument to justify why larger and more established funds tend to perform better than smaller and less established funds. The earlier successes and financial stability have made the established funds less risk averse, leading to increased success.

Lossen (2006) presents a systematic analysis of impact of diversification on private equity fund performance using a unique and proprietary sample of 100 private equity funds with 2871

different fund investments. Both specialization and diversification arguments as explainers of fund returns are considered. Different types of diversification studied are: diversification across number of portfolio companies, diversification across time, diversification across financing stages, diversification across industries, and diversification across countries. The findings of the study are mixed. In line with specialization hypothesis, the rate of return of sample funds decreased with diversification across financing stages. However, in line with diversification hypothesis, the rate of return of sample funds increased with diversification across industries.

Sapienza and Gupta (1992) studied the product market scope of the U.S. venture capital firm portfolios. In their research they investigated both the industry diversification and geographic diversification preferences between different types of venture organizations. The results indicate that venture organizations that specialize in early stage ventures prefer less industry diversity and narrower geographic scope relative to other venture organizations and that corporate venture organizations prefer less industry diversity but broader geographic scope than non-corporate venture organizations. The results also indicate that larger venture organizations prefer greater industry diversity and broader geographic scope than smaller venture organizations and that provision of small business investment companies (SBIC) financing by venture organization has no impact on preferences regarding industry diversity but is associated with a preference for narrower geographic scope.

2.2.6 *Captive funds and fund manager incentives*

In general, incentive schemes in independent private equity funds are reported to be surprisingly uniform. Most independent partnerships charge a management fee of around 2% of committed capital during investing period and around the same percentage of invested capital after the investment period. Very common carried interest charged by most fund managers is 20% of the fund returns above agreed hurdle rate, often zero (Sahlman 1990).

The compensation structures of captive funds such as corporate venture capital funds and private equity subsidiaries of investment banks, on the other hand, generally differ from those of independent private equity partnerships. Typical corporate venture capital program differs from the independent private equity partnership in that it is typically organized as a corporate division or a subsidiary rather than a partnership and the fund managers generally have much lower

incentive based compensation. The private equity subsidiaries of commercial and investment banks typically retain the partnership structure and the fund managers have higher incentive based compensation programs than corporate venture organizations but still lower than independent partnership fund managers. The lower incentives may have negative effect on fund returns on gross-of-fees basis as fund managers investment decisions may be biased towards lower risk projects. Also, higher incentives may attract experienced fund managers from captive funds to independent private equity firms. Net-of-fees, however, the host organization saves the incentive payments payable to investment managers which have positive effect on net-fund returns.

Gompers and Lerner (1998), study the successfulness of corporate venture capital programs in relation to independent partnerships. They find out that corporate venture investments are associated with between 18% and 30% higher valuations and those by independent funds associated with 7% and 18% lower valuations. On the other hand, they find that corporate venture investments in companies considered strategically important for the host organization perform no worse than those by independent partnerships.

2.2.7 Fund syndication

Syndication refers to more than one fund jointly investing in target company. There are several motives for syndication. One of the most basic reasons is risk sharing (Wilson 1968). Joint investment allows each investor to invest smaller share of capital, which facilitates diversification if investment would otherwise represent excessively large share in investor's portfolio.

Other syndication motives have to do with specialized resources and how informed the investors are. Investing jointly with another fund provides the lead investor an important second opinion about the quality of investment target. This can lead to better quality investment decisions compared to solo investment (Lerner 1994). Also, well connected, reputable venture capitalists with relevant expertise are known to provide many kinds of advantage to portfolio companies. The resource based motive for syndication is that different investors have complementary beneficial resources that provide value added for the target firm (Lerner 1994, Manigart 2002) and ultimately to the fund.

Admati and Pfleiderer (1994) note that there are informational asymmetries between the initial venture investor and later potential investors. A venture capitalist who is involved in the daily operations of the firm may exploit this information advantage by overstating the proper price for securities in the next financing round. The only way to avoid this behavior is if the lead venture capitalist maintains a constant share of the firm's equity. This requires that later rounds must be syndicated.

Lakonishok, Shleifer, Thaler, and Vishny (1991) suggest that there is an incentive for the venture capitalist funds to window dress. That is, it is hard for potential investors to confirm the performance data of venture organization's previous funds. Among other sources, the potential investors look at the prior investments of venture organization. For these reasons, it makes sense for venture organization to invest late in a successful venture even though the expected financial returns available are only modest as the future potential investors are able to observe that venture organization was an investor in successful company but they do not have a way to tell whether it was early or later stage investor or what was the actual profitability of the deal. Early stage investors are willing to let other venture organizations to participate in later rounds in expectation of reciprocation (Lerner 1994).

2.2.8 Buyout fund investments and leverage

The degree of agency problems arising from asymmetric information is significantly lower in buyout investments than in venture capital investments. Also, the inherent risk of the portfolio companies is usually significantly smaller in buyout funds where most of the portfolio companies are characterized by steady and positive cash flows. Partly because of this, typical characteristic of buyout deals is high degree of leverage, which is the reason that these deals are generally referred as leveraged buyouts (LBOs). In 2007, according to Bloomberg, typical degree of leverage in buyout deal was two thirds or three quarters of debt from total value of deal.

The well known theorem of Modigliani and Miller (1958) that states that the value of firm should, in absence of taxes, asymmetric information, transaction costs, bankruptcy costs, and differential borrowing rate between individuals and corporations, be irrelevant of the capital structure. In other words, it should not be necessary for buyout deals to be leveraged as the investors could leverage themselves. However, when corporate taxes are considered, pure debt

financing becomes the optimal capital structure. If in addition bankruptcy costs are taken into account, the optimal capital structure should lie where the benefits of debt exactly offset present value of bankruptcy costs.

Axelson, Strömberg, and Weisbach (2007) show that financing structure where fund managers capture fraction of excess fund returns and that requires the fund to be levered deal by deal results in more optimal incentive structure for fund managers. Another study by Axelson, Jenkinson, Strömberg, and Weisbach (2007) shows evidence that determining factors of public company capital structure and buyout transaction capital structure are different. It also shows that buyout funds tend to lever up to the maximum extent possible while the availability and cost of debt acts as the disciplining mechanism and that use of leverage is positively related to transaction prices. Increased availability of debt in 1990s and 2000s is attributed mainly to the development of syndicated debt market. Kaplan and Stein (1993) also show that boom in junk bond markets of the later 1980s contributed to higher transaction prices in the buyout market.

3 Research hypotheses

This chapter presents the main hypotheses tested in this study. The hypotheses are derived from earlier venture capital and private equity research that was reviewed in the literature study part. As there are only few existing papers that extensively study diversification as dependent variable, most hypotheses are developed based on other phenomena observed in earlier research. Different assumptions of the consequences of these to fund concentration were used to build testable hypotheses.

According to Gompers (1996), there is an incentive for first time fund managers to grandstand, that is, to engage in actions that signal their quality to the potential investors, in order to secure financing for their subsequent funds. Gompers shows that new venture funds tend to take their portfolio companies public earlier than optimal and therefore experience more under pricing in IPO than more seasoned venture organizations. The logic of grandstanding may apply to diversification decisions as well as degree of diversification affects the risk adjusted portfolio return and probability that fund manager can favorably signal its quality to investors.

For example, assume that there is some expected return on venture capital investments, that investment returns are normally distributed, and that to attract investors in its follow on funds, the fund manager must exceed some hurdle rate that signals the quality of fund managers to the investors. If this hurdle rate is lower than expected rate on venture capital investments, then it is beneficial for fund manager to diversify as diversification decreases portfolio variance and increases the probability that he will be able to raise a follow-on fund. On the other hand, if hurdle rate is above expected rate, then investors are better off if they concentrate as concentration increases total portfolio variance. Formally:

$$(1) \qquad \begin{aligned} & r_{hurdle} > r_{expected} \Rightarrow \\ & P(N(r_{expected}, \sigma_1) > r_{hurdle}) > P(N(r_{expected}, \sigma_2) > r_{hurdle}) \forall \sigma_1 > \sigma_2 \end{aligned}$$

This gives rise to two complementary hypotheses of which first assumes that fund managers use diversification as a lever to maximize their probability to raise follow-on funds and the second one that outperformance of market is needed to secure investors in follow-on funds.

Outperformance is defined to mean performance which exceeds expected return of venture capital investments.

H1a: There is a significant difference in fund concentration between first time funds and follow-on funds

H1b: First time funds need to outperform the market in order to secure investors in their follow-on funds. This will incentivize the fund managers to focus in most promising investment opportunities leading to lower degree of diversification than follow-on funds.

The level of experience, reputation, and establishment of private equity firm are likely to be related to scope of fund manager networks and their access to deal flow. Generally, access to deal flow and scope of networks tends to grow more significant over time. With larger amount of potential high quality investment targets, it is expected that funds will be more diversified. Additional hypothesis regarding fund manager experience is then made.

H2: Less established fund managers have more limited access to deal flow than more established fund managers. Due to more limited investment universe, funds with smaller sequence numbers tend to be more concentrated than funds with higher sequence numbers.

Inflows and outflows of capital in asset class have been reported to have significant effect on venture capital fund returns. Especially large inflows of capital into funds tend to negatively affect the subsequent performance of the funds (Gompers 1998). This negative performance caused by increased capital supply is explained by disconnectedness of venture capital market from the general equity market and the finite amount of good venture capital deals available at any given point in time. It is possible that the increased deal competition forces funds to widen their investment focus and seek investment targets beyond their preferred scope. This would cause the funds to invest in more diversified set of companies than they would otherwise prefer to invest if competition was less intense.

H3: Increased capital commitments in private equity funds will force more funds to compete for the same deals. Increased competition and shortage of attractive investment opportunities will force the funds to seek investment opportunities outside their preferred scope leading to higher degree of diversification.

The demand for venture capital is a related issue and also has effect on the fund returns and potentially fund diversification. Ceteris paribus, increase in demand for venture capital will lead to more investment opportunities for the funds and thus deintensified deal competition. Gompers (1998) reports that two significant drivers of demand for venture capital are level of R&D investment and level of capital gains taxes. Lower capital gains tax rate makes it more attractive for corporate managers to become entrepreneurs instead. Increased R&D investment in turn will tend to lead to new inventions and new technology. Financing further development and commercialization of these results will tend to increase demand for venture capital.

Although, it could be argued that increased demand of venture capital would have an opposite effect on fund diversification than increased supply of capital, this is not necessarily so straightforward. As research and development is a significant driver of venture capital demand and because research and development tends to produce primarily new ideas and technologies, it is possible that the new investment opportunities generated will not be available at the old industrial segments and exploiting these new investment opportunities would thus lead to increased fund diversification. If R&D tends to produce only marginally different new inventions the increased demand will be shown under the old industrial categories and the diversificatory effect will be opposite to increased supply of capital. Although two different effects are possible, I will expect that majority of new R&D induced new investment opportunities are found in old categories.

H4: Increase in research and development investment will increase demand for venture capital which will deintensify deal competition allowing funds to invest in their preferred investment focus areas thus decreasing fund diversification.

The size of firm and fund may also affect tendency to diversify. For example, the larger the funds pool of investment capital relative to target market, the more limited are the investment opportunities of the fund in that market. Because each market is likely to contain better and worse alternative targets and because of competition on deals, it is expected that the larger size of fund will increase tendency to diversify. Larger capital pool may also increase the fund managers' confidence in their abilities.

H5: Funds with larger investment capital pools tend to be more diversified than funds with smaller pools of capital

Corporate venturing subsidiaries of non-financial firms typically invest in industries of strategic interest to the host organization. The motives for corporate venturing are roughly two-fold involving direct and indirect motives. Direct motives involve new business creation, growth and diversification through new ventures. Indirect motives include strategic renewal, development of new competencies and technologies, promoting diversity and innovative corporate culture, and learning through exploration (Backholm 1999). It is likely that in general, although diversificatory motives are possible, corporate ventures tend to focus on related key industries around the main business of the host organization. This should lead to lower diversification of corporate venture capital funds compared to non-corporate venture capital funds seeking pure financial return. Furthermore, if the motive for diversification were pure risk reduction, it would be unlikely that this diversification would be pursued through high risk venture capital investments (Gupta and Sapienza 1992).

H6: Corporate venturing subsidiaries of non-financial corporations are expected to focus on industries of strategic interest to host organization and to be less diversified in terms of portfolio company industries than private partnerships seeking primarily financial return

4 Data and research methods

4.1 Overview of data

The primary source of data in this research is the VentureXpert database, published by Venture Economics, a Thomson Financial company. VentureXpert, along with Dow Jones VentureOne, is one of the most comprehensive databases about private equity financings, private equity backed M&A transactions, and private equity backed initial public offerings, and industry statistics about fund performance. It is estimated that the data covers about 90% of U.S. private equity financings.

The core data set that is used in this study is obtained from VentureXpert disbursements database. This database contains information about financing rounds of portfolio companies. For each financing round, the database contains information about the portfolio company that received the financing, basic round data such as date and amount invested, information about the funds that invested in company, and the respective private equity firms that manage the funds. From this data, the approximate contents of each funds portfolio can be deduced and several different kinds of diversification measures calculated.

The filtering criteria to obtain the base sample were as follows. First, it was required that the home nation of both firm and fund was U.S. Second, it was required that the fund size and firm capital under management were both over $10 million dollars. It has to be noted that although it was required that firm and fund are U.S. based, no criteria for portfolio companies were imposed. Therefore, the sample also contains foreign investments made by funds. The effect of this is minor however as only approximately ten percent of financing rounds are directed at foreign companies. Lower bound of $10 million dollars leaves out significant number of micro funds and individual angel investors. Excluding these has two functions. First, the data available for small funds is likely to be of lower quality than larger funds. For example, it is more likely that data values are missing. Second, additional problems may arise from private investments of individuals through classification problems and the different nature of these investments.

The initial sample consists of about 72936 investment rounds in portfolio companies, 29049 distinct portfolio companies, 4907 distinct private equity funds, and 1847 private equity firms.

The base sample was further filtered so that only funds belonging to venture capital, buyout, and generalist private equity classes were retained. Mezzanine funds, funds of funds, and specialty funds such as energy, real estate, and distressed debt were filtered out. The filtered funds account for relatively small portion of the funds but are potentially quite different from the major categories of venture capital and buyouts. As these types of funds are not the main focus of this study, they are better filtered out.

Other data that are used as control variables include annual change in NASDAQ Composite index, annual change in gross domestic product (GDP), annual change in economywide research and development (R&D) investment, and annual change in capital committed in private equity funds, and the level of corporate bond yields. NASDAQ Composite index levels are obtained from Yahoo Finance, gross domestic product levels and Moody's Baa grade seasoned corporate bond yield figures from Federal Reserve Bank of St.Louis, and R&D investment from National Science Foundation (NSF). The committed capital figures are obtained from VentureXpert commitments database.

4.2 Discussion of sample selection and potential biases

Due to the nature and availability of the data, it must be considered whether there is possibility that results could be distorted by some systematic bias in the sample. The most relevant biases include selection bias, survivorship bias, and look ahead bias.

Selection bias is generally caused by the fact that it is more likely for transactions related to successful deals to be publicized and recorded by private equity research firms than transactions related to less successful deals. Data could be missing regarding the transaction or the data about transaction could be missing altogether. For example, financing rounds of unsuccessful deals could be left unobserved or the data could be incomplete. The likelihood of bad quality data should be greater with smaller transactions. The variables used in this study should not be overly correlated with success or failure of private equity deal, therefore it is unlikely that selection bias should be significant issue. Fund size limit of $10 million dollars is partly in place to reduce the effect of possible selection bias.

Survivorship bias is generally an issue if performance of funds is studied as the general tendency is that for a first time fund that performed poorly, it is very hard for the managers to raise follow-on funds, even though the bad performance might have been simply adverse luck. Therefore, good performers are generally overrepresented. Regarding degrees of diversification, survivorship bias should not be a significant issue as existing research does not indicate that degree of diversification and performance would be automatically related to each other. Diversification strategy may yield benefits in some case where specialization strategy may yield benefits in others.

Lookahead bias on the other hand is prevalent in the sample and has to be accounted for. This is because funds raised near the end of the sample period are most likely not fully invested during the sample period and because the increased probability that financing rounds might not have been recorded in database by Venture Economics is higher. Therefore, for the funds raised near the end of the sample, the available sample of financing rounds is not necessarily representative of the true realized portfolio when the fund is fully invested. According to Ljungqvist and Richardson (2003), it takes three and six years, respectively, to invest 56,9% and 90,5% of committed capital. Ljungqvist and Richardson also note that funds do not always invest all the capital committed.

Regarding time diversification and number of portfolio companies, look ahead bias will certainly have major effect on results biasing time diversification and number of portfolio companies of recently raised funds downward. Regarding industry and stage diversification, look ahead bias may be less of a problem if the investment patterns in industries and stages are time independent. Even if this were true, however, small number of investments made to date places too much weight on individual observations and will introduce noise if not bias. To control these issues, I will only study funds that have vintage year no later than year 2003 and that have at least 10 distinct companies in their portfolios.

4.3 Descriptive statistics

4.3.1 Firms and funds

Table 1 shows descriptive statistics regarding firms that manage the funds in the sample. It can be seen that the firms are geographically concentrated in few major hubs. About 50% of the firms are either located in New York City, San Francisco area in California, and Massachusetts near Boston. Vast majority of the firms are private equity firms investing own capital, most others categories represent private equity subsidiaries of financial institutions, and corporate venture capital programs.

It can be seen that the industry is quite young as about 75% of the firms in business have been founded at 1987 or later, that is, less than about 20 years ago. There are large variations in the firm capital under management. This is primarily because firms operate venture capital funds, buyout funds, or both. Venture capital funds in average, tend to be smaller than buyout funds. The median capital under management for firms is 135 million dollars.

Table 1 Sample firm descriptive statistics

Descriptions of private equity firm characteristics in the sample

Number of firms	1847

Panel 1: Nominal attributes

Firm city	N	%
New York	296	16,0 %
Boston	96	5,2 %
San Francisco	92	5,0 %
Menlo Park	79	4,3 %
Chicago	67	3,6 %
Palo Alto	57	3,1 %
Los Angeles	37	2,0 %
Dallas	34	1,8 %
(Other)	1089	59,0 %

Firm state	N	%
California	452	24,5 %
New York	339	18,4 %
Massachusetts	186	10,1 %
Texas	97	5,3 %
Illinois	93	5,0 %
Connecticut	82	4,4 %
Pennsylvania	66	3,6 %
New Jersey	49	2,7 %
(Other)	483	26,2 %

Firm investment type	N	%
Private Equity Firm Investing Own Capital	1332	72,1 %
Investment/Merchant Bank Subsidiary or Affiliate	88	4,8 %
Private Equity Advisor or Fund of Fund Mgr	75	4,1 %
Corporate Venture Program	70	3,8 %
Affiliate/Subsidary of Oth. Financial. Instit.	55	3,0 %
Investment/Merchant Bank Investing Own or Client Funds	39	2,1 %
SBIC Not elsewhere classified	34	1,8 %
Commercial Bank Affiliate or Subsidiary	28	1,5 %
(Other)	126	6,8 %

Firm fees charged	N	%
(Not available)	759	41,1 %
ROI of primary concern, do not charge fees	733	39,7 %
ROI most important, but chg. closing fees, service fees, etc.	325	17,6 %
Other	17	0,9 %
Function primarily in service area, receive contingent fee in cash or equity	8	0,4 %
Professional fee required whether or not deal closes	5	0,3 %

Panel 2: Quantitative attributes

Firm capital under management (M$)	
Mean	870,5
Standard deviation	3316,8
Min	10,0
First quartile	50,0
Median	135,0
Third quartile	486,0
Max	74000,0

Year firm founded	
Mean	1993,0
Standard deviation	11,9
Min	1850
First quartile	1987
Median	1996
Third quartile	2000
Max	2008

Table 2 shows descriptive statistics regarding funds in the sample. Like with private equity firms, it can be seen that funds are based in the same principal private equity hubs as are the firms. In terms of numbers, venture capital funds form the majority of the fund types, buyout funds being the second major class of funds. The remaining funds mainly represent mezzanine funds, funds of funds, and generalist private equity. Most venture capital funds prefer early stage or balanced stage investments. Smaller number of funds specializes in later stage and expansion financing.

Table 2 Sample fund descriptive statistics

Descriptive statistics of initial sample of private equity funds.

Number of funds	4907

Panel 1: Nominal attributes

Fund city	N	%
New York	878	17,9 %
Boston	368	7,5 %
Menlo Park	349	7,1 %
San Francisco	284	5,8 %
Chicago	192	3,9 %
Palo Alto	162	3,3 %
Los Angeles	94	1,9 %
Washington	94	1,9 %
Dallas	76	1,5 %
(Other)	2410	49,1 %

Fund state	N	%
California	1308	26,7 %
New York	963	19,6 %
Massachusetts	637	13,0 %
Illinois	238	4,9 %
Connecticut	230	4,7 %
Texas	201	4,1 %
Pennsylvania	132	2,7 %
New Jersey	122	2,5 %
Maryland	98	2,0 %
(Other)	978	19,9 %

Fund investment type	N	%
Venture Capital	3196	65,1 %
Buyout	1127	23,0 %
Mezzanine	185	3,8 %
Fund of Funds	155	3,2 %
Generalist Private Equity	134	2,7 %
Other Private Equity	110	2,2 %

Fund stage focus	N	%
Early Stage	1411	28,8 %
Buyouts	1076	21,9 %
Balanced Stage	1030	21,0 %
Later Stage	387	7,9 %
Expansion	241	4,9 %
Mezzanine Stage	186	3,8 %
Seed Stage	135	2,8 %
Fund of Funds	127	2,6 %
Generalist	113	2,3 %
(Other)	201	4,1 %

Fund type	N	%
PRIV	3697	75,3 %
IBANK	427	8,7 %
FINCORP	310	6,3 %
CORPVEN	176	3,6 %
SECFOF	146	3,0 %
EGRN	40	0,8 %
INDIV	28	0,6 %
SBIC	23	0,5 %
DEVEL	16	0,3 %
(Other)	44	0,9 %

Fund raising status	N	%
Had final close	3643	74,2 %
Liquidated	662	13,5 %
(Not available)	331	6,7 %
Had close, still raising	216	4,4 %
Had final close, downsize	50	1,0 %
No close, still raising	5	0,1 %

Fund sequence type	N	%
Follow-on	3416	69,6 %
New	1058	21,6 %
Sole	423	8,6 %
(Not available)	10	0,2 %

Panel 2: Quantitative attributes

Fund vintage year	
Mean	1997,0
Standard deviation	7,4
Min	1958
First quartile	1994
Median	1999
Third quartile	2002
Max	2007

Fund size (M$)	
Mean	306,8
Standard deviation	878,6
Min	10,0
First quartile	35,0
Median	95,0
Third quartile	259,1
Max	21700,0

Table 3 shows the descriptive statistics related to portfolio companies. It can be seen that investments are primarily domestic. Only 10% of private equity financings of U.S. based funds are directed abroad. Of the foreign investment targets, Western Europe accounts for about half. Of domestic investments, it can be seen that company states and cities are tightly correlated with the states and cities of associated private equity firms and funds. That is, the firms and funds tend to invest in companies that are geographically near them. Investments are principally made in information technology, medical and life science, and non-high technology companies. The first quartile of company founding years is 1984. Therefore, it can be seen that investments are primarily made in young companies rather than older and more established ones. This is consistent with the role of venture capitalists as financiers of new growth business.

Table 3 Sample portfolio companies descriptive statistics

Descriptive statistics of portfolio companies	
Number of portfolio companies	29049

Panel 1: Nominal attributes

Company nation	N	%
United States	25938	89,3 %
United Kingdom	570	2,0 %
Canada	308	1,1 %
China	230	0,8 %
France	228	0,8 %
Germany	197	0,7 %
Israel	157	0,5 %
Japan	150	0,5 %
(Other)	1271	4,4 %

Company state	N	%
California	7896	27,2 %
Non-US	2546	8,8 %
Massachusetts	2517	8,7 %
Texas	1730	6,0 %
New York	1629	5,6 %
Pennsylvania	957	3,3 %
Illinois	853	2,9 %
New Jersey	823	2,8 %
(Other)	10098	34,8 %

Company world region	N	%
North America	26277	90,5 %
Western Europe	1244	4,3 %
East Asia	566	1,9 %
Middle East	158	0,5 %
Southern Europe	138	0,5 %
SouthEast Asia	133	0,5 %
Northern Europe	111	0,4 %
Southern Asia	111	0,4 %
(Other)	311	1,1 %

Company city	N	%
New York	995	3,4 %
San Francisco	744	2,6 %
San Jose	580	2,0 %
San Diego	500	1,7 %
Sunnyvale	462	1,6 %
Mountain View	448	1,5 %
Santa Clara	436	1,5 %
(Other)	24884	85,7 %

Company industry / 1	N	%
Information Technology	15016	51,7 %
Non-High Technology	9741	33,5 %
Medical/Health/Life Science	4291	14,8 %

Company industry / 2	N	%
Non-High-Technology	9741	33,5 %
Computer Related	9174	31,6 %
Communications and Media	4005	13,8 %
Medical/Health/Life Science	2943	10,1 %
Semiconductors/Other Elect	1837	6,3 %
Biotechnology	1348	4,6 %

Panel 2: Quantitative attributes

Company founded	
Mean	1989,0
Standard deviation	17,7
Min	1684
First quartile	1984
Median	1995
Third quartile	1999
Max	2008

4.3.2 Financing rounds

Figure 1 shows the total amount of dollars invested by U.S. based private equity funds in terms of financing rounds and dollar volume. The Internet bubble in turn of the millennium can be seen in the figure as a sharp spike which is primarily caused by vastly increased amount of venture capital invested in new Internet based companies. It can also be seen that before 1980s the financing volume is very low. This is both caused by smaller size of venture capital and private equity industry at the time and less systematic data collection.

Figure 1 U.S. fund financing rounds through 1965-2007

Total amount of invested equity and number of financing rounds year by year of U.S. based private equity funds. Left vertical axis and the line with triangles shows the total disbursed capital in billions of U.S. dollars, and the right vertical axis and the line with squares shows the number of financing rounds. The data covers all private equity investments in Thomson VentureXpert disbursements database with fund size over 10 million dollars.

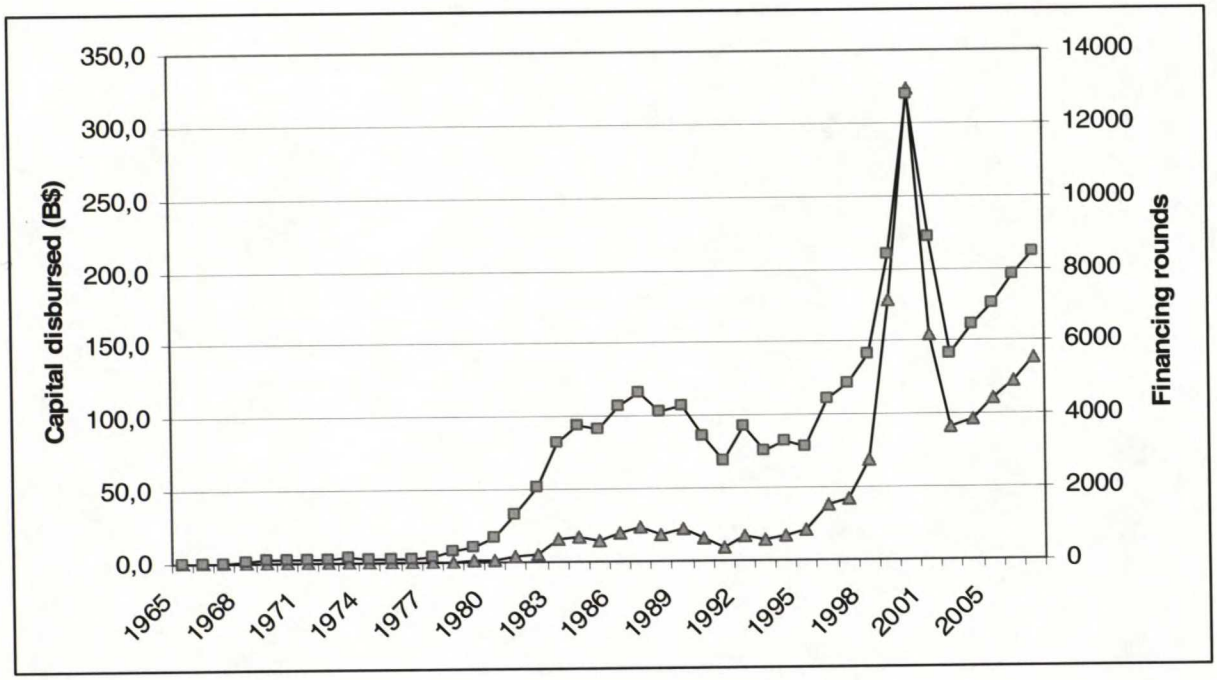

Table 4 shows descriptive statistics about the financing rounds in the sample. The total amount of rounds in the sample is 72936. It can be seen that majority of the financing rounds are venture capital financing rounds focused on expansion and later stage investments. Early stage investments correspond to about 25% of the financing rounds. Buyout transactions cover only 10% of the rounds by numbers. However, considering capital involved, the average size of average buyout transaction is higher than average venture capital transaction. About seventy five percent of companies receive four or fewer financing rounds, the average being 3,1. However, the highest number of financing rounds per company in the data set is 27. Syndication in financing rounds is common, the median number of different investors at each financing round being two and mean being 3,1. Pre money valuation of portfolio companies at each financing round had median of 18,9 million dollars, and median of 51,8 million dollars.

Table 4 Sample financing rounds descriptive statistics

Descriptive statistics of financing rounds

Number of financing rounds	72936

Panel 1: Nominal attributes

Financing stage /1	N	%
Expansion	23730	32,5 %
Early Stage	13286	18,2 %
Other	9860	13,5 %
Later Stage	9396	12,9 %
Buyout/Acquisition	8536	11,7 %
Startup/Seed	7357	10,1 %
(Unknown)	771	1,1 %

Financing stage /2	N	%
Expansion	23536	32,3 %
Later Stage	14550	19,9 %
Startup	13641	18,7 %
Acquisition	7916	10,9 %
Oth Early Stage	4076	5,6 %
Public Market	3316	4,5 %
Seed	2926	4,0 %
Special Sit.	1126	1,5 %
VC Partnership	1078	1,5 %
Unknown	771	1,1 %

Financing stage /3	N	%
Expansion	13463	18,5 %
Second Stage	10073	13,8 %
First Stage	9210	12,6 %
Third Stage	5869	8,0 %
Bridge Loan	4960	6,8 %
Startup	4431	6,1 %
LBO	4181	5,7 %
Early Stage	3944	5,4 %
Seed	2926	4,0 %
Acq. for Expansion	2800	3,8 %
Other Later Stage	2480	3,4 %
(Other)	8599	11,8 %

Panel 2: Quantitative attributes

Round number	
Mean	3,1
Standard deviation	2,6
Min	1
First quartile	1
Median	2
Third quartile	4
Max	27

Number of investors in round	
Mean	3,1
Standard deviation	2,7
Min	1
First quartile	1
Median	2
Third quartile	4
Max	34

Round size (th$)	
Mean	11309,9
Standard deviation	80162,4
Min	0,8
First quartile	870,0
Median	3042,0
Third quartile	9100,0
Max	13700000,0

Round pre-money valuation (M$)	
Mean	51,8
Standard deviation	157,2
Min	-462,6
First quartile	7,4
Median	18,9
Third quartile	48,3
Max	7842,0

4.4 General research methodology

Fund diversification is studied utilizing both univariate and multivariate analysis. Univariate analysis aims to answer the questions whether there are statistically significant differences between funds that belong to different classes of interest and whether there are statistically significant differences between funds raised at different time periods. Multivariate analysis is used to study effect of different fund specific properties as explainers of fund diversification. Univariate analysis is carried out mainly utilizing two-tailed separate variance t-test to test

differences between different fund classes and time periods. Multivariate analysis is based on multiple ordinary least squares (OLS) method with different model specifications.

The concentration measures that are used for testing differences in univariate framework and that are used as dependent variables in multivariate framework are specified in the next section. Some variables are available in multiple levels. For example, company industry classification is available in six different levels of which each lower level contains more fine grained categorization than its parent level. Inferences can then be made based on observed degrees of concentration at each level. Company financing stage also has multiple levels. Typical pattern is that the concentration measure of interest is smaller the lower the respective industry classification level. Regression results are reported only for selected levels to save space, typically highest, lowest, and some intermediate level. This does not generally lead to loss of significant informational content. Observed results are interpreted and hypotheses are tested against them.

4.5 Dependent variables

Industry concentration measures

The Herfindahl-Hirschman index (HHI) is a common but simple measure that is most often used to gauge the degree of concentration in an industry. For example, the competition authorities of U.S. and many other countries, routinely use HHI as a metric against which to check whether proposed mergers and acquisitions would create excessive monopolistic power. The HHI is simply the sum of squares of market shares of all industry firms and is formally defined in equation (1). In this context, of course, definition of market is crucial for HHI to yield meaningful results.

$$HHI = \sum_{i=1}^{N} s_i^2 \qquad (2)$$

In HHI formula N is the number of firms in industry and s_i the respective percentage market share of each firm. The basic HHI formula yields the values between 1/N and one, where N is the number of different classes. To normalize the range between zero and one, normalized HHI (NHHI) can be calculated as follows:

(3) $$NHHI = \frac{HHI - 1/N}{1 - 1/N} = \frac{N \cdot (HHI - 1)}{N - 1}$$

In this study, I use regular HHI measure to gauge private equity fund concentration in specific industries and financing stages. The market share s_i is the percentage share of capital that the fund has invested in specific industry or financing stage. The concentration on financing stages is calculated on financing round level

For each fund, the portfolio companies and their industry classifications are obtained from the financing round data. In the HHI formula, N is the number of distinct industries that fund has holdings in and s_i is the percentage share of capital invested in portfolio companies in the respective industry segment relative to total amount of capital invested by the fund.

The industry classifications from which concentration measures are calculated are available in six different levels: Industry class, Industry major group, industry minor group, and industry subgroups through 1 to 3. The groupings are based on proprietary classification of Thomson Venture Economics. For some companies, mainly those that have gone public, SIC codes are also available and could be used for concentration measure calculation but since this data is intermittent at best, SIC codes are not used.

Regarding industrial classifications, there is a problem with the standard HHI index. This arises from the fact that industrial classifications are hierarchical. If the index calculation is performed at any given level of hierarchy then all items at that hierarchy level become equal in weight. On the other hand however, it can be reasonably argued that two companies below the same higher level categorization are closer to each other than two companies that are below different hierarchical higher level categories. For example, it can be argued that fund that invested one dollar in Biotechnology company and another one in Computer software company is more diversified than fund that invested one dollar in Internet company and another dollar in Computer software company. To account for this effect and to test alternative metrics, I define a metric that I choose to call hierarchical Herfindahl-Hirschman index (HHHI). The metric contains parameter gamma that can be used to adjust the distance between different higher level categories. With gamma of one, the formula yields just the same results as the standard HHI index calculated at

lowest hierarchy level (L_{max}). Higher gamma values than one yield lower HHHI scores when diversification occurs between higher level categories. The formula is defined recursively as:

$$HHHI_L = \sum_{i=1}^{N_L} s_{i,L}^2 (HHHI_{L-1})^{\gamma}, 1 \leq L \leq L_{\max} \quad (4)$$

$$HHHI_0 = 1 \quad (5)$$

In the formula $s_{i,L}$ is the percentage share of i:th item in level L relative to its parent at hierarchy level L-1. Gamma is an arbitrary heuristic parameter that has no unit and no natural interpretation.

Financing stage diversification measures

Stage of each portfolio company is available in three levels for each company financing round. The stage levels are based on proprietary classification of Thomson Venture Economics. The same HHI based concentration measures that are used to gauge fund industry diversification are used to gauge the financing stage diversification.

Time diversification measures

Time diversification is a measure of how fast the fund invests its capital. Fast investment time implies that the time based diversification of fund is low and long investment time implies that the time based diversification is higher. In spirit of Lossen (2003), I calculate time based diversification metric as follows:

$$TDI_f = \left(\sum_{k=1}^{N_f} \frac{I_{k,f}}{NINV_{k,f}} \right)^{-1} \left(\sum_{k=1}^{N_f} \frac{I_{k,f}}{NINV_{k,f}} (T_{k,f} - T_{1,f}) \right) \quad (6)$$

The diversification is simply invested capital weighted sum of investment times relative to fund's first investment. N_f is the number of financing rounds the fund has participated in, $I_{k,f}$ is the total amount invested in target company in financing round k, $NINV_{k,f}$ is the number of investors in financing round k, $T_{k,f}$ is the time in years of the financing round k. As the information about each investor's relative shares is not available in the data, it is assumed that all investors invest in

equal proportions. This may not be exactly true in case of any single investment but in context of time diversification indicator it should not introduce a systematic bias.

Syndication measures

The tendency of fund to syndicate its investments, that is, to co-invest with other investor, is calculated as the capital weighted sum of number of investors at each financing round that the fund participated in. The syndication metric is simply invested capital weighted sum of number of investors at each round. N_f is the number of financing rounds the fund has participated in, $I_{k,f}$ is the total amount invested in target company in financing round k, $NINV_{k,f}$ is the number of investors in financing round k. The formula simplifies to equation (5).

$$SND_f = \left(\sum_{k=1}^{N_f} \frac{I_{k,f}}{NINV_{k,f}} \right)^{-1} \left(\sum_{k=1}^{N_f} I_{k,f} \right) \tag{7}$$

Since it is not known, what were the exact proportions of capital invested by each fund participating in the financing round; it is assumed that all round investors invested in equal proportions.

Correlation between dependent variables

To illustrate how different dependent variables are related to each other, the Table 5 shows correlation matrix for different dependent variables. It can be seen that adjacent levels of hierarchical variables are significantly correlated with each other, which is unsurprising. It can also be seen that time diversification, syndication, and number of portfolio companies are mostly inversely correlated with the industry and stage concentration variables.

Table 5 Correlation coefficients between dependent variables

Pearson correlation coefficients between dependent variables. Industry HHIn denotes fund industry concentration measured at level n of industry classification. Stage HHIn measures fund stage concentration measured at classification level n. Capital weighted round timing measures the time diversification of fund. Capital weighted number of round investors measures the tendency of fund managers to syndicate and number of portfolio companies measures the number of distinct companies in fund's portfolio.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Industry HHI1	1,000											
(2) Industry HHI2	0,639	1,000										
(3) Industry HHI3	0,514	0,835	1,000									
(4) Industry HHI4	0,542	0,790	0,963	1,000								
(5) Industry HHI5	0,487	0,713	0,815	0,799	1,000							
(6) Industry HHI6	0,265	0,555	0,658	0,598	0,787	1,000						
(7) Stage HHI1	0,305	0,423	0,371	0,281	0,398	0,491	1,000					
(8) Stage HHI2	0,311	0,402	0,343	0,270	0,371	0,452	0,975	1,000				
(9) Stage HHI3	0,223	0,410	0,392	0,307	0,444	0,606	0,847	0,837	1,000			
(10) Capital weighted round timing	-0,222	-0,126	-0,154	-0,162	-0,249	-0,201	-0,199	-0,197	-0,149	1,000		
(11) Capital weighted number of round investors	0,146	-0,157	-0,089	-0,009	-0,137	-0,198	-0,138	-0,110	-0,135	0,026	1,000	
(12) Number of portfolio companies	-0,157	-0,198	-0,228	-0,255	-0,321	-0,353	-0,166	-0,166	-0,172	0,534	0,073	1,000

4.6 Independent variables

4.6.1 Variable descriptions

This section describes the independent variables used in this study. These variables are used to explain differences in fund portfolio diversity in regression analyses. Some nominal variables are also used in univariate analysis to divide the funds into different categories.

Firm capital under management

Firm capital under management is the amount of capital in millions of dollars that the private equity firm managing the fund has under management. In theory, this figure should be approximately equal to sum of capital amounts committed in each of the funds managed by the firm. Firm capital under management proxies how well established the firm is in the private equity market, its success, its reputation, and number of funds it is managing. In regression analysis, logarithm of capital under management is used rather than straight number as it is assumed that additional capital has diminishing marginal effect on fund dependent variables.

Firm type

Firm type is a nominal variable that describes the type of private equity firm. Most common firm type is private equity firm investing own capital. In addition to that, there are several other types of firms such as corporate subsidiaries and affiliates, corporate venture programs, subsidiaries and affiliates of investment banks, commercial banks, and insurance companies. There are also firms that have significant business in advisory and consulting services instead of being simply investors seeking pure return on investment. In regressions the different firm type values are coded as set of binary dummy variables assuming value of one if firm belongs to the respective category and zero otherwise.

Fund sequence number and fund sequence type

Fund sequence number indicates the ordinal number of the fund raised by the private equity firm. The fund sequence number may act as a proxy for firm experience, fund manager reputation and other related things. Fund sequence type is a nominal variable indicating whether the fund is first time fund, a follow-on fund or sole fund. Sole fund indicates that it is both the first and the last fund raised by the firm.

Fund stage focus

Fund stage focus is a nominal variable indicating the stated investment focus of the fund with regard to development stage of the target companies. For buyout funds, there is only one stage which is noted with term buyouts. For venture capital firms the stage focus may be one of the following: seed stage, early stage, expansion, later stage, or balanced stage. The fund stage focus is not to be confused with the company stage at each financing round. The fund stage focus is coded as set of binary dummy variables assuming value of one if fund has the respective stage focus and zero otherwise. Balanced stage is used as base case if one of the dummies must be left out to avoid dummy trap.

Fund investment type

Fund investment type is a nominal variable denoting the types of investments that the fund is focused in. The fund investment type may be either venture capital, buyout, or generalist private

equity. This variable is not used in regressions but is rather used to break down observations into different subsamples.

Fund size

Fund size indicated the amount of capital committed in fund in millions of dollars. The amount of capital is not necessarily equal to amount invested by the fund but rather the maximum amount the fund can invest without needing to raise more capital. Logarithm of the fund size is used in the regressions rather than the dollar amount as it is expected that additional capital has diminishing effect on dependent variables of interest.

Fund type

Fund type is a nominal variable that indicates the fund ownership type. This variable is closely related to the firm type variable but is different in that it holds a smaller number of categorizations and that has some subtle differences, all of which are not exactly known. In this study, fund type may assume values: PRIV for private partnerships, FINCORP for funds affiliated with financial corporations, IBANK for funds affiliated with investment banks, and CORPVEN for corporate venture programs. These categories are coded as set of binary dummy variables. PRIV is used as the base case if one of the dummies must be left out to avoid dummy trap.

Firm age at fund inception

Firm age at fund inception is the difference between fund vintage year and the firm founding year. It indicates the amount of years the firm has been operating prior to raising the fund. Firm age at fund inception serves as a proxy to gauge firm experience and reputation. Logarithm of firm age at inception plus one is used in regressions. There are observations in which firm founding year is later than fund vintage year. In these cases value of zero is used.

Firm or fund from private equity hub

There are certain locations in U.S. where venture capital and private equity activity tends to focus in. About half of the private equity firms operate in one of the three states of California, New

York, and Massachusetts. The dummy variable takes value of one if firm or the fund is located in one of these states and zero otherwise.

Change in capital committed in private equity funds

This control variable measures the percentage change of total capital committed in U.S. based venture capital and private equity funds at fund vintage year relative to the previous year. The capital committed in private equity funds each year is obtained from VentureXpert commitments database. The commitments are calculated over all recorded capital commitments in U.S. based funds.

Change in NASDAQ index

This control variable measures the percentage change in NASDAQ Composite index at fund vintage year relative to the previous year. The annual changes are calculated from the trading volume weighted daily closing prices each year.

Change in economywide R&D investment

This control variable measures the percentage change in economywide research and development investment at fund vintage year relative to previous year. The R&D investment statistics are collected from National Science Foundation (NSF) and contain both investments by private sector, academic institutions, and government funding.

Change in gross domestic product

Gross domestic product measures the total value of services produced in an economy at given period of time. Hence, it is an indicator of overall economic activity. Annual gross domestic product change is used as a control variable in regressions. The data series is obtained from Federal Reserve Bank of St.Louis.

Bond yield

Moody's Baa-grade seasoned corporate debt yield is used a control variable. Availability and price of debt financing is an important determinant of buyout fund returns that tend to use

significant amounts of leverage. Regardless of the potential effect of this variable, I do not make any predictions exactly how bond yields should affect fund diversification. The bond yields are obtained from Federal Reserve Bank of St.Louis.

4.6.2 Correlation between variables

Table 6 shows the correlation matrix of variables presented in previous section. The variables whose mutual correlation exceeds level 0,5 are highlighted. In general, excessive correlation between variables may lead to multicollinearity problems in regression models and has to be accounted for. In principle, multicollinearity does not affect the validity of OLS regression coefficient estimates but may lead to overestimation of respective t-statistics. In other words, significance of coefficients may be overestimated if multicollinearity is present.

It remains debatable what degree of correlation produces multicollinearity problems. Mathematically, model specification matrix can be inverted and model coefficients solved if all absolute correlation coefficients are less than one. In practice, absolute correlation has to be significantly less. Conservatively, absolute values lower than 0,5 of correlation coefficients should not cause problems. On the other hand, there is general consensus that the correlation coefficients of over 0,9 will be problematic. In this study, I will accept correlations up to 0,6 and attempt to break down variable pairs having mutual correlation over this where possible.

The table shows that variables fund type and firm type have significant correlation between each other. This is not surprising as the variables tend to measure more or less the same thing but from somewhat different viewpoints. For these reasons, firm type dummies and fund type dummies are not used together in the same regression specifications.

Variables fund investment type and fund stage focus have extreme correlation in case of buyout funds and generalist private equity funds. This is because stage focus will always have value Buyouts when investment type has value Buyout and stage focus will most often be Generalist when fund investment type has value Generalist Private Equity. In other words, fund sequence type variable is only meaningful for venture capital funds. To break down this correlation, regressions are independently run for two different sets of data: venture capital funds and buyout funds. Generalist private equity funds is rather small group compared to the main categories of venture capital and buyout funds, therefore regressions are not separately ran for generalist

private equity funds. In this process, variable fund investment type is also dropped altogether from regression variables as the regressions are now ran independently and the variable would be redundant.

In variable fund sequence type, the Follow-on dummy has extreme negative correlation between dummy New, which is natural. To break down these correlations, dummy variables Sole and New are replaced by a single dummy variable "Is fund first time fund?" and dummy variable Follow-on is dropped. The new dummy variable will be one for fund sequence types Sole or New and zero otherwise.

Table 6 Correlation coefficients between independent variables

Pearson correlation coefficients between independent variables used in this study. Variable pairs that have absolute correlation coefficient over 0,5 are highlighted. Variables shown are: logarithm of private equity firm capital under management, private equity firm classification code dummies (Firm type), fund investment type dummies (Fund investment type), fund sequence number, fund sequence type dummies (Fund sequence type), fund stage focus dummies (Fund stage focus), logarithm of fund committed capital in millions of dollars, fund type classification code dummies (Fund type), private equity firm age at fund inception, indicator whether fund or firm is located in three private equity hub states CA,NY,MA (Is fund or firm from PE hub?), annual change in capital committed to private equity funds at fund vintage year (Commit capital delta), annual change in NASDAQ Composite index at vintage year (NASDAQ Composite delta), annual change in U.S. R&D investment at vintage year (R&D investment delta), annual change in gross domestic product at vintage year (GDP Delta), and average Moody's Baa-grade corporate debt yield at vintage year (Bond yield)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)
(1) log(Firm capital under management)	1,00																																					
(2) Firm type: Private Equity Firm Investing Own Capital	0,04	1,00																																				
(3) Firm type: Commercial Bank Affiliate or Subsidiary	0,11	-0,34	1,00																																			
(4) Firm type: Corporate Venture Program	-0,16	-0,33	-0,02	1,00																																		
(5) Firm type: Investment Merchant Bank Subsidiary or Affiliate	-0,06	-0,40	-0,03	-0,03	1,00																																	
(6) Firm type: Affiliate Subsidary of Oth Financial Instit	0,00	-0,29	-0,02	-0,02	-0,02	1,00																																
(7) Firm type: Investment Merchant Bank Investing Own or Client Funds	-0,07	-0,28	-0,02	-0,02	-0,02	-0,02	1,00																															
(8) Firm type: Private Equity Advisor or Fund of Fund Mgr	0,07	-0,40	-0,03	-0,03	-0,03	-0,02	-0,02	1,00																														
(9) Firm type: Venture Consulting Firm	-0,02	-0,29	-0,02	-0,02	-0,02	-0,02	-0,02	-0,02	1,00																													
(10) Firm type: Investment Management Firm Finance Consulting	0,00	-0,12	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	1,00																												
(11) Firm type: Insurance Firm Affiliate or Subsidiary	0,08	-0,16	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	0,00	1,00																											
(12) Firm type: Corporate Subsidiary or Affiliate	-0,08	-0,11	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	-0,01	0,00	0,00	1,00																										
(13) Fund investment type: Venture Capital	-0,20	0,04	-0,03	0,05	-0,04	0,01	-0,02	-0,11	0,04	0,02	0,02	0,02	1,00																									
(14) Fund investment type: Buyout	0,18	-0,02	0,02	-0,04	0,00	0,00	0,04	0,09	-0,04	-0,02	-0,02	-0,02	-0,89	1,00																								
(15) Fund investment type: Generalist Private Equity	0,07	-0,05	0,04	-0,02	0,08	-0,02	-0,02	0,05	-0,02	-0,01	-0,01	-0,01	-0,42	-0,04	1,00																							
(16) Fund sequence number	0,43	-0,04	0,04	-0,08	0,03	-0,02	-0,04	0,15	0,01	-0,03	-0,01	-0,02	-0,05	0,02	0,09	1,00																						
(17) Fund sequence type: Follow on	0,32	0,05	-0,05	-0,11	0,02	-0,03	-0,03	0,07	0,02	-0,02	-0,02	-0,08	-0,03	0,01	0,05	0,42	1,00																					
(18) Fund sequence type: New	-0,17	-0,03	0,05	0,04	-0,02	0,04	0,02	-0,05	0,00	0,03	0,03	0,00	0,01	0,01	-0,04	-0,36	-0,86	1,00																				
(19) Fund sequence type: Sole	-0,30	-0,03	0,00	0,14	-0,01	-0,01	-0,01	-0,03	-0,03	-0,01	-0,02	0,16	0,04	-0,03	-0,03	-0,17	-0,39	-0,13	1,00																			
(20) Fund stage focus: Early Stage	-0,11	0,16	-0,12	-0,01	-0,07	-0,03	-0,07	-0,11	0,04	-0,02	0,00	-0,04	0,27	-0,24	-0,10	-0,02	0,05	-0,06	0,01	1,00																		
(21) Fund stage focus: Balanced Stage	0,01	-0,07	0,07	0,02	0,00	0,03	0,04	-0,01	0,01	0,03	0,03	0,05	0,23	-0,21	-0,08	0,00	-0,03	0,04	-0,02	-0,58	1,00																	
(22) Fund stage focus: Later Stage	0,02	-0,14	0,10	0,01	0,08	0,04	0,03	0,08	-0,04	0,02	0,01	0,03	0,08	-0,09	0,02	0,02	-0,05	0,02	0,05	-0,26	-0,22	1,00																
(23) Fund stage focus: Expansion	-0,02	0,01	-0,04	0,03	0,01	-0,03	0,02	0,03	-0,03	-0,01	-0,02	-0,01	0,08	-0,07	-0,03	-0,02	-0,03	0,03	0,01	-0,19	-0,16	-0,07	1,00														
(24) Fund stage focus: Buyouts	0,19	-0,02	0,02	-0,04	0,00	0,00	0,03	0,09	-0,04	-0,02	-0,02	-0,02	-0,89	1,00	-0,02	0,02	0,01	0,01	0,01	-0,03	-0,24	-0,21	-0,09	-0,07	1,00													
(25) Fund stage focus: Seed Stage	-0,07	0,05	-0,03	0,00	-0,03	-0,02	-0,02	-0,03	0,03	-0,01	-0,01	-0,01	0,06	-0,05	-0,03	-0,04	0,01	0,00	-0,01	-0,15	-0,13	-0,06	-0,04	-0,05	1,00													
(26) Fund stage focus: Generalist	0,06	-0,08	0,05	-0,02	0,10	-0,02	-0,02	0,07	-0,02	-0,01	-0,01	-0,01	-0,35	-0,04	0,85	0,08	0,03	-0,02	-0,03	-0,10	-0,08	-0,04	-0,03	-0,04	-0,02	1,00												
(27) log(Fund size)	0,53	0,07	-0,03	-0,06	-0,05	0,02	-0,05	0,03	-0,04	0,00	0,03	-0,05	-0,27	0,26	0,06	0,36	0,28	-0,25	-0,10	-0,02	-0,10	0,01	0,00	0,26	-0,12	0,04	1,00											
(28) Fund type: PRIV	0,11	0,60	-0,36	-0,34	-0,32	-0,26	-0,19	0,07	-0,02	-0,10	-0,07	-0,12	0,04	-0,01	-0,06	0,05	0,13	-0,07	-0,13	0,19	-0,13	-0,14	0,03	-0,01	0,07	-0,05	0,06	1,00										
(29) Fund type: IBANK	0,03	-0,35	0,16	-0,04	0,53	-0,03	0,27	-0,05	0,01	-0,01	-0,02	-0,01	-0,03	0,00	0,07	0,08	0,04	-0,04	-0,01	-0,15	0,09	0,09	0,01	0,00	-0,05	0,09	0,00	-0,57	1,00									
(30) Fund type: CORPVEN	-0,19	-0,30	-0,03	0,74	0,02	-0,03	-0,03	-0,04	0,08	-0,01	-0,01	0,26	0,07	-0,06	-0,03	-0,10	-0,15	0,03	0,24	0,01	0,03	0,01	0,00	-0,06	-0,02	-0,02	-0,08	-0,45	-0,05	1,00								
(31) Fund type: FINCORP	-0,05	-0,33	0,41	-0,02	-0,05	0,45	0,05	-0,03	-0,04	0,17	0,13	-0,01	-0,08	0,07	0,04	-0,09	-0,13	0,11	0,02	-0,15	0,08	0,11	-0,05	0,07	-0,05	0,01	-0,03	-0,60	-0,07	-0,05	1,00							
(32) log(Firm age at fund inception + 1)	0,35	0,04	-0,08	-0,07	0,00	0,04	0,03	0,05	-0,02	-0,03	-0,04	-0,06	-0,09	0,08	0,02	0,49	0,61	-0,51	-0,27	0,02	-0,05	-0,02	-0,01	0,08	-0,02	0,01	0,35	0,09	0,00	-0,12	-0,04	1,00						
(33) Is fund or firm from PE hub?	0,17	-0,03	-0,01	-0,01	0,05	0,02	0,02	0,03	0,01	-0,05	-0,04	-0,04	0,08	-0,06	-0,07	0,13	0,07	-0,06	-0,02	0,05	0,03	-0,01	-0,04	-0,05	-0,04	-0,03	0,11	-0,03	0,11	-0,02	-0,04	0,06	1,00					
(34) Committed capital delta	0,01	-0,06	0,10	0,03	-0,01	0,00	0,02	-0,01	-0,02	-0,02	0,01	0,14	0,02	-0,03	0,02	-0,08	-0,09	0,08	0,03	-0,05	0,04	0,04	0,00	-0,03	-0,01	0,04	-0,16	-0,08	0,04	0,06	0,03	-0,05	-0,01	1,00				
(35) NASDAQ Composite delta	0,03	-0,01	0,00	0,00	0,03	-0,01	0,02	0,01	-0,02	-0,01	0,00	-0,01	-0,04	0,07	-0,05	-0,08	-0,08	0,13	-0,07	-0,01	-0,06	0,05	0,04	0,07	-0,05	-0,04	-0,11	0,00	0,00	-0,02	0,02	-0,05	-0,03	0,02	1,00			
(36) R&D investment delta	-0,07	0,00	0,01	-0,01	0,02	0,00	0,01	-0,02	-0,01	-0,03	-0,02	0,05	0,01	0,00	-0,03	-0,12	-0,14	0,16	-0,02	-0,04	0,01	0,03	0,03	0,01	0,00	-0,03	-0,16	-0,01	0,02	-0,02	0,02	-0,11	-0,03	0,16	0,57	1,00		
(37) GDP delta	-0,08	-0,06	0,12	0,03	-0,02	0,00	0,04	-0,03	0,03	-0,04	0,01	0,11	0,04	-0,06	0,02	-0,15	-0,15	0,14	0,03	-0,14	0,17	0,01	-0,03	-0,05	0,03	0,03	-0,32	-0,11	0,07	0,04	0,07	-0,18	0,00	0,35	-0,05	0,40	1,00	
(38) Bond yield	-0,12	-0,06	0,07	-0,01	0,07	0,01	0,04	-0,03	0,01	-0,03	-0,02	0,04	0,05	-0,05	-0,01	-0,19	-0,15	0,16	-0,01	-0,18	0,19	0,06	-0,07	-0,05	0,06	0,01	-0,40	-0,11	0,11	-0,02	0,07	-0,22	0,03	0,05	0,00	0,30	0,55	1,00

4.7 Regression models

The generic regression model used to study fund concentration in multivariate ordinary least squares (OLS) regression framework is shown in Equation 7. Dependent variable is the concentration metric that is being explained in the regression. The metrics examined in this study comprise of HHI industry concentration metric at levels one, four, and six, HHI stage concentration metrics at levels one, two, and three, capital weighted round timing, capital weighted round number of investors, and number of companies in fund portfolio. Regressions are run separately for venture capital funds and buyout funds.

$$
\begin{aligned}
&ConcentrationMetric = \\
&\beta_1(FirmType) + \beta_2(FundType) + \beta_3 \log(FirmCapitalUnderManagement) + \\
&\beta_4(FundStageFocus) + \beta_5(IsFirstTimeFund) + \beta_6(FundSequenceNumber) + \\
&\beta_7 \log(FundSize) + \beta_8 \log(FirmAgeAtFundInception + 1) + \\
&\beta_9(FirmOrFundFromPEHub) + \beta_{10}(CommittedCapitalDelta) + \\
&\beta_{11}(NASDAQCompositeDelta) + \beta_{12}(RDInvestmentDelta) + \beta_{13}(GDPDelta) + \\
&\beta_{14}(BAAGradeBondYield) + \varepsilon
\end{aligned} \tag{8}
$$

The generic regression model is not used as is but is further adjusted to obtain four alternative regression specifications. In the model, firm type and fund type are not used in same regression as these variables have significant amounts of overlap. Also, fund stage focus is not meaningful variable for buyout funds as it only assumes single value for buyout funds. Therefore, for each variable of interest, following regressions are run i) buyout funds without fund type and fund stage focus ii) buyout funds without firm type and fund stage focus iii) venture capital funds without fund type iv) venture capital funds without firm type.

Variables FirmType, FundType, FundStageFocus, are nominal or factor variables that assume finite set of discrete values not comparable with each other. Each such variable is coded as one binary dummy variable for each of the different nominal values the variable can assume. It should be noted that in regression analysis, a condition known as dummy variable trap can occur if exhaustive set of dummy variables is used as independent variables. For example, if there are two values for a variable (red and blue) then using both dummy variables isred and isblue would lead to perfect multicollinearity if intercept term is present in the model. If intercept term is

removed, then there can be one exhaustive set of dummy variables. In regressions used in this study, no intercept term is used and exhaustive dummy encodings are used for fund type and firm type variables. This makes fund type and firm type variables similar to intercepts for the respective fund types.

5 Results and Analysis

5.1 Univariate analysis

5.1.1 Diversification differences between venture capital fund categories

Table 7 shows the results of t-test of differences in mean fund industry concentration between different venture capital fund types. Concentration is measured in levels 1,4, and 6 of industrial classification. The results show that funds related to financial corporations and investment banks are more diversified than private funds and corporate venture programs in highest concentration level. In second concentration level, the results show that corporate venture programs are more concentrated than private funds and investment bank related funds. Investment bank related funds are also less concentrated than private funds. These results show that financial corporation and investment bank backed funds invest in significantly more diversified set of industries than other types of funds. Corporate venture funds on the other hand, tend to concentrate to smaller set of industries than other fund types. Evidence is consistent with the hypothesis which states that corporate venture capital funds should be more concentrated than funds that are primarily seeking financial return without other strategic interests.

Table 7 Differences in industry concentration between venture capital fund types

Separate variance two tailed t-test of difference in mean results regarding fund industry concentration. The differences are between different fund type categories. Diversification is measured with Herfindahl-Hirschman index at industrial classification levels 1, 4, and 6. Difference estimate in means is column variable minus row variable. Number in parentheses is the p-value associated with test. Stars signify significance levels of test (* indicates significance at 99% level, ** at 95% level, and * at 90% level).**

Panel 1: HHI1									
	(1)		(2)		(3)		(4)		N
(1) PRIV	0,000								1159
	(1,00)								
(2) CORPVEN	0,050		0,000						58
	(0,11)		(1,00)						
(3) FINCORP	-0,104	***	-0,153	***	0,000				80
	(0,00)		(0,00)		(1,00)				
(4) IBANK	-0,081	***	-0,130	***	0,023		0,000		79
	(0,00)		(0,00)		(0,49)		(1,00)		
N	1159		58		80		79		

Panel 2: HHI4

	(1)		(2)		(3)		(4)	N
(1) PRIV	0,000							1159
	(1,00)							
(2) CORPVEN	0,046	**	0,000					58
	(0,04)		(1,00)					
(3) FINCORP	-0,035	**	-0,081	***	0,000			80
	(0,03)		(0,00)		(1,00)			
(4) IBANK	-0,057	***	-0,103	***	-0,023		0,000	79
	(0,00)		(0,00)		(0,27)		(1,00)	
N	1159		58		80		79	

Panel 3: HHI6

	(1)		(2)		(3)		(4)	N
(1) PRIV	0,000							1159
	(1,00)							
(2) CORPVEN	0,023	**	0,000					58
	(0,05)		(1,00)					
(3) FINCORP	0,005		-0,018		0,000			80
	(0,68)		(0,28)		(1,00)			
(4) IBANK	-0,020	*	-0,043	***	-0,025		0,000	79
	(0,05)		(0,00)		(0,12)		(1,00)	
N	1159		58		80		79	

Table 8 shows the results of t-test of differences in mean fund industry concentration between venture capital fund sequence types. At highest level, there are no significant differences. In second level it can be seen that sole and new funds are more concentrated than follow-on funds. In third level sole funds are still more concentrated than follow-on funds but difference between new funds and follow-on funds becomes insignificant. However, in third level, sole funds are significantly more concentrated than new funds.

According to these results, first time funds are more concentrated than follow-on funds and that sole funds are more concentrated than new funds. Ending up as a sole fund is often regarded a sign of failure in that the firm was unable to raise a follow-on fund due to poor performance or other reason. It may also be that one reason for ending up as a sole fund is excessive portfolio concentration. The evidence shows support for hypothesis which states that there is a difference in tendency of first time funds to diversify and the hypothesis which states that first time funds tend to be more concentrated than follow-on funds due to need to outperform the market to signal their quality. The evidence is neither in contradiction with the hypothesis which states that due to more restricted access to deal flow and investment opportunities, funds with low sequence numbers tend to be more concentrated than funds with higher sequence numbers.

Table 8 Differences in industry concentration between venture capital fund sequence types

Separate variance two tailed t-test of difference in mean results regarding fund industry concentration. The differences are between different fund sequence type categories. Diversification is measured with Herfindahl-Hirschman index at industrial classification levels 1, 4, and 6. Difference estimate in means is column variable minus row variable. Number in parentheses is the p-value associated with test. Stars signify significance levels of test (* indicates significance at 99% level, ** at 95% level, and * at 90% level).**

Panel 1: HHI1

	(1)	(2)	(3)	N
(1) Follow-on	0,000			992
	(1,00)			
(2) Sole	-0,026	0,000		81
	(0,27)	(1,00)		
(3) New	-0,003	0,023	0,000	300
	(0,85)	(0,37)	(1,00)	
N	992	81	300	

Panel 2: HHI4

	(1)	(2)	(3)	N
(1) Follow-on	0,000			992
	(1,00)			
(2) Sole	0,046 **	0,000		81
	(0,01)	(1,00)		
(3) New	0,023 **	-0,022	0,000	300
	(0,03)	(0,26)	(1,00)	
N	992	81	300	

Panel 3: HHI6

	(1)	(2)	(3)	N
(1) Follow-on	0,000			992
	(1,00)			
(2) Sole	0,041 ***	0,000		81
	(0,00)	(1,00)		
(3) New	0,006	-0,035 ***	0,000	300
	(0,27)	(0,00)	(1,00)	
N	992	81	300	

Table 9 shows the results of t-test of differences in mean fund stage concentration between different venture capital fund types. In highest level the results show that corporate venture funds are more concentrated than private funds and funds associated with financial corporations and investment banks. The results are equivalent at all levels. From the data it can be seen that corporate ventures invest more in expansion stage deals and less in buyout stage deals and deals whose classification is unknown. The hypothesis formulated about corporate venture fund concentration made statement primarily about industry concentration but it is still interesting to notice that there is also difference in stage concentration.

Table 9 Differences in stage concentration between venture capital fund types

Separate variance two tailed t-test of difference in mean results regarding fund stage concentration. The differences are between different fund type categories. Diversification is measured with Herfindahl Hirschman index at stage classification levels 1,2, and 3. Difference estimate in means is column variable minus row variable. Number in parentheses is the p-value associated with test. Stars signify significance levels of test (* indicates significance at 99% level, ** at 95% level, and * at 90% level).**

Panel 1: HHI1

	(1)		(2)		(3)	(4)	N
(1) PRIV	0,000						1159
	(1,00)						
(2) CORPVEN	0,058	***	0,000				58
	(0,00)		(1,00)				
(3) FINCORP	-0,009		-0,067	***	0,000		80
	(0,48)		(0,00)		(1,00)		
(4) IBANK	-0,021	*	-0,079	***	-0,012	0,000	79
	(0,06)		(0,00)		(0,47)	(1,00)	
N	1159		58		80	79	

Panel 2: HHI2

	(1)		(2)		(3)	(4)	N
(1) PRIV	0,000						1159
	(1,00)						
(2) CORPVEN	0,055	***	0,000				58
	(0,00)		(1,00)				
(3) FINCORP	-0,001		-0,056	***	0,000		80
	(0,95)		(0,01)		(1,00)		
(4) IBANK	-0,016		-0,071	***	-0,015	0,000	79
	(0,18)		(0,00)		(0,37)	(1,00)	
N	1159		58		80	79	

Panel 3: HHI3

	(1)		(2)		(3)	(4)	N
(1) PRIV	0,000						1159
	(1,00)						
(2) CORPVEN	0,038	***	0,000				58
	(0,00)		(1,00)				
(3) FINCORP	0,013		-0,025		0,000		80
	(0,31)		(0,14)		(1,00)		
(4) IBANK	0,002		-0,036	**	-0,011	0,000	79
	(0,85)		(0,02)		(0,50)	(1,00)	
N	1159		58		80	79	

Table 10 shows the results of t-test of differences in mean fund stage concentration between venture capital fund sequence types. In highest level, results show that sole funds are more concentrated than both follow-on funds and new funds. This effect persists but gets smaller when going lower in classification levels. I assume that stage diversification is not primarily a portfolio risk reduction lever and this effect is not specifically supportive of the hypotheses made about first time fund concentration. Concentration on specific financing stages can be seen as a measure to reduce costs of asymmetric information but this view is also in contradiction with evidence that shows that more concentration leads to potentially worse results.

Table 10 Differences in stage concentration between venture capital fund sequence types

Separate variance two tailed t-test of difference in mean results regarding fund stage concentration. The differences are between different fund sequence type categories. Diversification is measured with Herfindahl-Hirschman index at stage classification levels 1, 2, and 3. Difference estimate in means is column variable minus row variable. Number in parentheses is the p-value associated with test. Stars signify significance levels of test (* indicates significance at 99% level, ** at 95% level, and * at 90% level).**

Panel 1: HHI1

	(1)		(2)		(3)	N
(1) Follow-on	0,000					992
	(1,00)					
(2) Sole	0,028	**	0,000			81
	(0,01)		(1,00)			
(3) New	-0,005		-0,033	***	0,000	300
	(0,46)		(0,01)		(1,00)	
N	992		81		300	

Panel 2: HHI2

	(1)		(2)		(3)	N
(1) Follow-on	0,000					992
	(1,00)					
(2) Sole	0,027	**	0,000			81
	(0,03)		(1,00)			
(3) New	-0,002		-0,030	**	0,000	300
	(0,76)		(0,03)		(1,00)	
N	992		81		300	

Panel 3: HHI3

	(1)		(2)		(3)	N
(1) Follow-on	0,000					992
	(1,00)					
(2) Sole	0,022	**	0,000			81
	(0,01)		(1,00)			
(3) New	0,008		-0,014		0,000	300
	(0,13)		(0,16)		(1,00)	
N	992		81		300	

5.1.2 Diversification differences in buyout fund categories

Regarding buyout funds, there are much less differences in different categories of funds. Also the number of observations is significantly smaller than in case of venture capital funds. Table 11 presents a summary of all diversification differences in different buyout fund categories having statistical significance over 90%. Due to small number of significant observations, all significant observations are shown in single table.

First, it must be noted that there are no significant observable differences in fund diversification metrics between fund sequence types (new, sole, follow-on). Otherwise as well, there are only few conclusions to be made. Although some results are shown as significant, the small amount of observations in many cases undermines their credibility. The evidence shows that investment or merchant bank subsidiaries and affiliates tend to be industrially more concentrated than other firm types. The evidence also shows that private equity advisors and fund of fund managers seem to syndicate less that private equity partnerships investing own capital.

Table 11 Concentration differences in buyout fund categories

Separate variance two tailed t-test of difference in mean results for buyout fund categories. Panel 1 shows differences in industry diversification metrics, panel 2 shows differences in stage diversification metrics, and panel 3 shows differences in other diversification metrics. Category variable presents the variable whose different values are compared against each other, category 1 shows the value of first category, and category 2 shows the value of second category. Estimated difference is the difference between categories. P-value indicates the p-value from t-statistic and significance presents the symbolic significance of result (* 99% significance ** 95% significance * 90% significance). Columns N describe number of observations in each category.**

Panel 1: Industry concentration

Category Variable	Metric	Category 1	Category 2	Est.Diff. (1)-(2)	P-value	Signif.	N (1)	N (2)
Firm type	HHI1	Investment/Merchant Bank Subsidiary or Affiliate	Private Equity Firm Investing Own Capital	0,243	0,030	**	4	99
Firm type	HHI1	Investment/Merchant Bank Subsidiary or Affiliate	Commercial Bank Affiliate or Subsidiary	0,217	0,086	**	4	4
Firm type	HHI1	Investment/Merchant Bank Subsidiary or Affiliate	Investment/Merchant Bank Investing Own or Client Funds	0,234	0,066	**	4	4
Firm type	HHI1	Investment/Merchant Bank Subsidiary or Affiliate	Private Equity Advisor or Fund of Fund Mgr	0,299	0,014	**	4	11
Firm type	HHI4	Affiliate/Subsidary of Oth, Financial, Instit,	Private Equity Firm Investing Own Capital	-0,102	0,000	***	2	99
Firm type	HHI4	Private Equity Advisor or Fund of Fund Mgr	Affiliate/Subsidary of Oth, Financial, Instit,	0,072	0,053	*	11	2
Fund type	HHI1	IBANK	PRIV	0,150	0,076	*	7	102
Fund type	HHI6	FINCORP	PRIV	0,104	0,057	*	15	102

Panel 2: Stage concentration

Category Variable	Metric	Category 1	Category 2	Est.Diff. (1)-(2)	P-value	Signif.	N (1)	N (2)
Firm type	HHI3	Investment/Merchant Bank Investing Own or Client Funds	(1) Private Equity Firm Investing Own Capital	-0,086	0,056	*	4	99

Panel 3: Time diversification, tendency to syndicate, number of portfolio companies

Category Variable	Metric	Category 1	Category 2	Est.Diff. (1)-(2)	P-value	Signif.	N (1)	N (2)
Fund type	Nbr companies	FINCORP	PRIV	14,273	0,076	*	15	102
Firm type	Round investors	Private Equity Advisor or Fund of Fund Mgr	Private Equity Firm Investing Own Capital	-0,818	0,002	***	11	99
Firm type	Nbr companies	Investment/Merchant Bank Investing Own or Client Funds	Private Equity Firm Investing Own Capital	-5,942	0,000	***	4	99

5.2 Multivariate analysis

5.2.1 Industry diversification

Table 12 shows the ordinary least squares (OLS) regression results with fund characteristics as independent variables and industry diversification metrics as dependent variables. Industry

diversification is measured with Herfindahl-Hirschman index (HHI) at levels one, four and six of company industry level classification. It can be seen that there is a significant difference between buyout funds and venture capital funds. For venture capital funds most variables are highly significant where as for buyout funds most are not. R-squared metrics show that variables do quite well in explaining industry concentration.

Buyout funds show practically no interesting results. It can be seen that in first level of industry classification firm type and fund type variables are significant at 99% level, which suggest that the main determinant of diversification is fund ownership type. GDP change is also significant but only at 90% level under the second regression specification.

Table 12 Fund industry diversification regression results

Ordinary least squares (OLS) regressions with fund industry diversification metrics as dependent variables. HHIn is HHI index calculated at the n:th level of industry classification hierarchy. Columns I-VI show results for buyout funds and columns VII-VIII show results for venture capital funds. Specifications I,II,III,VII,VIII,IX use private equity firm type variable to describe fund affiliation and specifications IV,V,VI,X,XI,XII use fund type variable to describe fund affiliation. Values in parentheses indicate t-statistic associated with estimate. Stars indicate significance level of estimate (* 99% significance ** 95% significance * 90% significance).**

	Dependent variables: Fund industry concentration											
	Buyout funds						Venture capital funds					
Independent variables	HHI1	HHI4	HHI6	HHI1	HHI4	HHI6	HHI1	HHI4	HHI6	HHI1	HHI4	HHI6
Firm type: Private Equity Firm Investing Own Capital	0,830 ***	0,254	0,191				0,807 ***	0,564 ***	0,323 ***			
	(4,66)	(1,55)	(1,47)				(17,44)	(17,12)	(19,42)			
Firm type: Commercial Bank Affiliate or Subsidiary	0,896 ***	0,376 *	0,379 **				0,828 ***	0,545 ***	0,326 ***			
	(4,20)	(1,91)	(2,44)				(13,51)	(12,48)	(14,80)			
Firm type: Investment/Merchant Bank Investing Own or Client Funds	0,799 ***	0,164	0,187				0,792 ***	0,558 ***	0,297 ***			
	(4,09)	(0,91)	(1,32)				(12,46)	(12,35)	(12,98)			
Firm type: Affiliate/Subsidary of Oth, Financial, Instit,	0,709 ***	0,115	0,156				0,777 ***	0,541 ***	0,315 ***			
	(3,08)	(0,54)	(0,93)				(12,73)	(12,44)	(14,37)			
Firm type: Investment Management Firm /Finance Consulting							0,745 ***	0,608 ***	0,384 ***			
							(7,68)	(8,80)	(11,02)			
Firm type: Corporate Venture Program							0,885 ***	0,607 ***	0,320 ***			
							(15,44)	(14,88)	(15,51)			
Firm type: Venture Consulting Firm							0,807 ***	0,570 ***	0,345 ***			
							(13,55)	(13,44)	(16,09)			
Firm type: Private Equity Advisor or Fund of Fund Mgr	0,754 ***	0,232	0,234 *				0,703 ***	0,522 ***	0,328 ***			
	(4,06)	(1,36)	(1,73)				(12,86)	(13,41)	(16,71)			
Firm type: Investment/Merchant Bank Subsidiary or Affiliate	1,044 ***	0,380 *	0,229				0,856 ***	0,550 ***	0,318 ***			
	(5,03)	(1,98)	(1,52)				(15,88)	(14,34)	(16,42)			
Firm type: Corporate Subsidiary or Affiliate							1,042 ***	1,018 ***	0,685 ***			
							(5,19)	(7,13)	(9,50)			
Firm type: Insurance Firm Affiliate or Subsidiary							0,656 ***	0,476 ***	0,269 ***			
							(5,89)	(6,01)	(6,71)			
Fund type: PRIV				0,822 ***	0,235	0,183				0,797 ***	0,561 ***	0,325 ***
				(4,63)	(1,44)	(1,42)				(17,34)	(17,13)	(19,47)
Fund type: CORPVEN										0,879 ***	0,599 ***	0,337 ***
										(16,89)	(16,15)	(17,85)
Fund type: FINCORP				0,876 ***	0,254	0,268 *				0,761 ***	0,543 ***	0,330 ***
				(4,65)	(1,47)	(1,97)				(14,65)	(14,65)	(17,49)
Fund type: IBANK				0,937 ***	0,347 *	0,233				0,767 ***	0,532 ***	0,319 ***
				(4,78)	(1,93)	(1,64)				(14,76)	(14,37)	(16,89)
log(Firm capital under management)	-0,014	-0,002	-0,005	-0,020	-0,003	-0,003	0,012 ***	0,000	-0,008 ***	0,011 **	0,000	-0,008 ***
	-(0,93)	-(0,11)	-(0,43)	-(1,36)	-(0,24)	-(0,24)	(2,63)	(0,06)	-(5,04)	(2,47)	-(0,12)	-(4,69)
Fund stage focus: Seed Stage							0,046	0,033	0,006	0,045	0,032	0,006
							(1,53)	(1,54)	(0,57)	(1,49)	(1,48)	(0,52)
Fund stage focus: Early Stage							0,076 ***	0,024 ***	0,005	0,074 ***	0,022 **	0,004
							(6,07)	(2,67)	(1,03)	(5,89)	(2,45)	(0,88)
Fund stage focus: Expansion							0,025	0,015	0,026 ***	0,024	0,014	0,025 ***
							(1,02)	(0,87)	(2,97)	(0,95)	(0,79)	(2,82)
Fund stage focus: Later Stage							-0,006	0,029 **	0,030 ***	-0,004	0,028 **	0,029 ***
							-(0,32)	(2,06)	(4,21)	-(0,21)	(1,96)	(4,12)
Is first time fund?	-0,024	0,015	0,034	-0,030	0,021	0,027	-0,001	-0,006	-0,003	0,000	-0,006	-0,004
	-(0,42)	(0,28)	(0,81)	-(0,53)	(0,40)	(0,66)	-(0,05)	-(0,57)	-(0,53)	(0,00)	-(0,49)	-(0,75)
Fund sequence number	-0,010	-0,009	-0,004	-0,006	-0,007	-0,004	-0,003 *	-0,001	0,001 *	-0,003 *	-0,002	0,001 **
	-(1,65)	-(1,64)	-(0,98)	-(1,10)	-(1,39)	-(1,02)	-(1,88)	-(1,20)	(1,69)	-(1,92)	-(1,28)	(2,00)
log(Fund size)	0,003	0,010	-0,004	0,003	0,008	-0,008	0,004	-0,021 ***	-0,014 ***	0,005	-0,020 ***	-0,014 ***
	(0,15)	(0,57)	-(0,27)	(0,15)	(0,48)	-(0,55)	(0,59)	-(4,21)	-(5,56)	(0,68)	-(4,11)	-(5,84)
log(Firm age at fund inception + 1)	0,001	0,020	0,024	-0,002	0,023	0,021	-0,016 **	-0,018 ***	-0,005 **	-0,017 **	-0,018 ***	-0,006 ***
	(0,03)	(0,97)	(1,46)	-(0,10)	(1,09)	(1,25)	-(2,51)	-(3,76)	-(2,16)	-(2,55)	-(3,82)	-(2,59)
Is fund or firm from PE hub?	0,020	-0,011	-0,029	0,011	-0,020	-0,016	0,074 ***	0,011	-0,009 **	0,079 ***	0,012	-0,009 **
	(0,53)	-(0,32)	-(1,07)	(0,29)	-(0,60)	-(0,61)	(6,43)	(1,37)	-(2,10)	(6,83)	(1,50)	-(2,22)
Committed capital delta	-0,022	-0,029	-0,039	-0,009	-0,009	-0,024	-0,014 **	-0,014 ***	-0,004 *	-0,013 **	-0,014 ***	-0,004 *
	-(0,53)	-(0,75)	-(1,31)	-(0,23)	-(0,23)	-(0,81)	-(2,25)	-(3,17)	-(1,72)	-(2,09)	-(3,05)	-(1,73)
NASDAQ Composite delta	-0,025	0,105	0,028	0,010	0,109	0,006	-0,125 ***	-0,020	-0,006	-0,127 ***	-0,023	-0,009
	-(0,27)	(1,25)	(0,42)	(0,11)	(1,34)	(0,09)	-(4,91)	-(1,12)	-(0,68)	-(4,98)	-(1,27)	-(1,03)
R&D investment delta	-0,829	-1,162	-0,348	-1,147	-1,184	-0,192	1,706 ***	0,142	-0,030	1,740 ***	0,176	0,003
	-(0,93)	-(1,41)	-(0,53)	-(1,31)	-(1,47)	-(0,30)	(6,59)	(0,77)	-(0,32)	(6,72)	(0,95)	(0,03)
GDP delta	2,267	3,282 **	2,658 **	2,269	2,809 *	2,101 *	-1,308 ***	-0,544 **	-0,173	-1,320 ***	-0,552 **	-0,204
	(1,37)	(2,15)	(2,20)	(1,40)	(1,89)	(1,79)	-(3,74)	-(2,18)	-(1,38)	-(3,80)	-(2,23)	-(1,62)
Bond yield	-0,020	-0,013	-0,010	-0,016	-0,008	-0,006	-0,023 ***	-0,013 ***	-0,007 ***	-0,022 ***	-0,012 ***	-0,007 ***
	-(1,63)	-(1,13)	-(1,12)	-(1,31)	-(0,72)	-(0,68)	-(7,87)	-(6,11)	-(6,63)	-(7,51)	-(5,90)	-(6,49)
Multiple R-squared	0,928	0,823	0,757	0,925	0,817	0,751	0,930	0,833	0,783	0,929	0,831	0,776
Adjusted R-squared	0,916	0,794	0,718	0,915	0,794	0,719	0,928	0,830	0,778	0,928	0,829	0,773
Residual standard error	0,186	0,171	0,135	0,187	0,172	0,135	0,195	0,139	0,070	0,195	0,139	0,071
F-Statistic	80,1	29,0	19,4	95,8	34,8	23,5	654,3	247,0	178,2	892,2	335,8	236,6
F numerator df	17	17	17	14	14	14	26	26	26	19	19	19
F denominator df	106	106	106	109	109	109	1287	1287	1287	1294	1294	1294

Venture capital funds show more interesting results. Fund type and firm type are both significant at 99% level for each regression specification. It can be seen that coefficients for corporate venture funds are notably higher than for other types of funds, which is consistent with the hypothesis. Firm capital under management is positive at level one and negative at level six, both at 99% significance level. Also, fund size is negative at level four and level six, also at 99%

significance level. This shows evidence for the hypothesis that larger funds tend to be more diversified. However, the diversification only seems to occur at lower levels of industrial classification suggesting that pure risk reduction is not the primary motive. Rather, the effect could be due to the fact that larger funds are able to invest in larger number of companies and those companies are likely to be from different industrial classifications at low levels of classification hierarchy.

The results also show that early stage funds tend to be more concentrated at levels one and four of the hierarchy. Also, expansion stage funds tend to be more concentrated at level six and later stage funds at levels four and six. For early stage funds, possible explanation is that early stage funds may be mainly investing in popular industries mainly in growth sectors such as information technology, biotechnology, and medical technology, rather than non-high technology industries. On the other hand, later stage companies are generally larger in size than early stage companies and later stage fund of same size than early stage fund can invest in fewer companies thus increasing its concentration.

Venture capital fund sequence does not seem to have significant effect on industry concentration, which does not lend support to hypothesis that scope of fund manager networks and experience would affect fund concentration. Venture capital firm age at fund inception in turn seems to have diversificatory effect on fund portfolios measured at all levels. One explanation is that funds of more established firms are likely to be also be larger. Other explanation is that more established firms have acquired more experience, have access to more extensive networks, and have access to more deal flow.

If the firm or fund is from the private equity hub states of California, Massachusetts, or New York, then the fund is likely to be more concentrated at first level and more diversified at sixth level. This could be caused by the fact that these hubs may be concentrated on specific industries. For example, state of California which accounts about one quarter of private equity investments nationwide is well known for its thriving information technology cluster mainly concentrated in the "silicon valley" in southern part of San Francisco bay area. On the other hand, there exists wide variety of technology firms that are extremely differentiated at lower levels of industry classification. This explains the results observed.

All the macroeconomic control variables seem to be significant to fund concentration in first classification level. Change in NASDAQ Composite Index returns, change in GDP, and level of interest rates all seem to decrease industry concentration. On the other hand, increases in R&D investment seem to increase concentration of venture capital funds. Overall, it could be said that venture capital fund concentration is highly affected by key parameters of overall economic activity. On the other hand, it is also possible that some dramatic event, such as information technology boom and bust at the turn of the millennium is driving these results. It is hard, however, to control for this potential effect as there is only limited amount of funds that are completely unaffected by its effects.

5.2.2 Stage diversification

Table 13 shows the ordinary least squares (OLS) regression results with fund characteristics as independent variables and stage diversification metrics as dependent variables. Stage diversification is measured with Herfindahl-Hirschman index (HHI) at levels one and three of company stage level classification. It can be seen that there is a significant difference between buyout funds and venture capital funds. For venture capital funds most variables are highly significant where as for buyout funds most are not. R-squared metrics show that variables do quite well in explaining stage concentration.

For buyout funds the results show that the only significant factors affecting stage diversification are fund size and whether the private equity firm is investment/merchant bank subsidiary or affiliate. Larger buyout funds tend to be more stagewise more concentrated than smaller funds and investment bank subsidiaries tend to be more concentrated than other firm types. Regarding fund size, the result is not surprising as the largest buyout funds presumably tend to invest in larger targets that tend to be mature stage companies thus leading to greater stage concentration. It is surprising however that this relation is quite weak and also that firm capital under management has insignificant impact.

Table 13 Fund stage diversification regression results

Ordinary least squares (OLS) regressions with fund stage diversification metrics as dependent variables. HHIn is the Herfindahl-Hirschman index calculated at n:th level of stage classification. Columns I-IV show results for buyout funds and columns V-VIII show results for venture capital funds. Specifications I,II,V,VI use private equity firm type variable to describe fund affiliation and specifications III,IV,VII,VIII use fund type variable to describe fund affiliation. Values in parentheses indicate t-statistic associated with estimate. Stars indicate significance level of estimate (* 99% significance ** 95% significance * 90% significance).**

	Dependent Variables: Fund stage concentration							
	Buyout funds				Venture capital funds			
Independent variables	HHI1	HHI3	HHI1	HHI3	HHI1	HHI3	HHI1	HHI3
Firm type: Private Equity Firm Investing Own Capital	0,231	0,214			0,528 ***	0,383 ***		
	(1,04)	(1,08)			(23,95)	(21,50)		
Firm type: Commercial Bank Affiliate or Subsidiary	0,261	0,276			0,577 ***	0,436 ***		
	(0,98)	(1,16)			(19,76)	(18,45)		
Firm type: Investment/Merchant Bank Investing Own or Client Funds	0,277	0,148			0,503 ***	0,366 ***		
	(1,14)	(0,68)			(16,63)	(14,96)		
Firm type: Affiliate/Subsidary of Oth, Financial, Instit,	-0,012	0,164			0,522 ***	0,368 ***		
	-(0,04)	(0,64)			(17,96)	(15,66)		
Firm type: Investment Management Firm /Finance Consulting					0,492 ***	0,370 ***		
					(10,65)	(9,91)		
Firm type: Corporate Venture Program					0,570 ***	0,410 ***		
					(20,85)	(18,59)		
Firm type: Venture Consulting Firm					0,576 ***	0,413 ***		
					(20,31)	(17,99)		
Firm type: Private Equity Advisor or Fund of Fund Mgr	0,230	0,215			0,519 ***	0,376 ***		
	(1,00)	(1,04)			(19,92)	(17,85)		
Firm type: Investment/Merchant Bank Subsidiary or Affiliate	0,400	0,492 **			0,530 ***	0,386 ***		
	(1,55)	(2,12)			(20,64)	(18,59)		
Firm type: Corporate Subsidiary or Affiliate					0,709 ***	0,437 ***		
					(7,42)	(5,66)		
Firm type: Insurance Firm Affiliate or Subsidiary					0,558 ***	0,372 ***		
					(10,52)	(8,69)		
Fund type: PRIV			0,241	0,196			0,522 ***	0,381 ***
			(1,09)	(0,98)			(23,81)	(21,47)
Fund type: CORPVEN							0,574 ***	0,408 ***
							(23,17)	(20,35)
Fund type: FINCORP			0,235	0,207			0,516 ***	0,386 ***
			(1,01)	(0,98)			(20,86)	(19,25)
Fund type: IBANK			0,192	0,252			0,520 ***	0,394 ***
			(0,79)	(1,14)			(20,99)	(19,67)
Fund stage focus: Seed Stage					0,027 *	0,029 **	0,027 *	0,030 ***
					(1,89)	(2,47)	(1,89)	(2,60)
Fund stage focus: Early Stage					0,017 ***	0,008	0,016 ***	0,008 *
					(2,76)	(1,57)	(2,72)	(1,72)
Fund stage focus: Expansion					0,070 ***	0,046 ***	0,068 ***	0,046 ***
					(5,94)	(4,88)	(5,79)	(4,79)
Fund stage focus: Later Stage					0,050 ***	0,037 ***	0,052 ***	0,038 ***
					(5,29)	(4,89)	(5,52)	(5,04)
log(Firm capital under management)	0,004	0,014	-0,006	0,004	-0,007 ***	-0,007 ***	-0,006 ***	-0,006 ***
	(0,21)	(0,85)	-(0,31)	(0,25)	-(3,18)	-(4,04)	-(2,68)	-(3,52)
Is first time fund?	0,077	0,052	0,059	0,043	0,010	0,010	0,009	0,009
	(1,08)	(0,82)	(0,85)	(0,67)	(1,31)	(1,63)	(1,18)	(1,46)
Fund sequence number	-0,009	-0,005	-0,007	-0,003	0,001	0,001	0,001	0,001
	-(1,20)	-(0,83)	-(0,95)	-(0,40)	(0,80)	(1,02)	(1,11)	(1,31)
log(Fund size)	0,043 *	0,003	0,048 **	0,008	-0,006 *	-0,012 ***	-0,006 *	-0,012 ***
	(1,84)	(0,14)	(2,02)	(0,38)	-(1,82)	-(4,36)	-(1,95)	-(4,60)
log(Firm age at fund inception + 1)	0,011	0,004	0,006	0,003	0,005	0,004	0,003	0,002
	(0,40)	(0,17)	(0,21)	(0,12)	(1,45)	(1,40)	(1,10)	(0,93)
Is fund or firm from PE hub?	-0,027	-0,017	-0,032	-0,019	0,010 *	0,006	0,010 *	0,005
	-(0,58)	-(0,40)	-(0,71)	-(0,45)	(1,84)	(1,37)	(1,73)	(1,17)
Committed capital delta	-0,031	-0,017	-0,029	-0,015	-0,006 **	-0,005 **	-0,006 **	-0,005 **
	-(0,60)	-(0,36)	-(0,56)	-(0,33)	-(2,01)	-(2,19)	-(2,00)	-(2,22)
NASDAQ Composite delta	-0,048	-0,089	-0,012	-0,052	-0,038 ***	-0,023 **	-0,038 ***	-0,023 **
	-(0,42)	-(0,87)	-(0,11)	-(0,52)	-(3,12)	-(2,33)	-(3,17)	-(2,31)
R&D investment delta	0,230	0,596	-0,227	0,205	0,506 ***	0,241 **	0,511 ***	0,236 **
	(0,21)	(0,60)	-(0,21)	(0,21)	(4,10)	(2,42)	(4,14)	(2,36)
GDP delta	-0,569	0,483	-0,370	0,668	-0,444 ***	-0,236 *	-0,402 **	-0,200
	-(0,28)	(0,26)	-(0,18)	(0,37)	-(2,66)	-(1,75)	-(2,43)	-(1,49)
Bond yield	0,010	0,001	0,016	0,007	-0,013 ***	-0,008 ***	-0,013 ***	-0,008 ***
	(0,63)	(0,04)	(1,06)	(0,54)	-(9,17)	-(6,83)	-(9,09)	-(6,96)
Multiple R-squared	0,866	0,794	0,861	0,782	0,941	0,910	0,940	0,909
Adjusted R-squared	0,844	0,761	0,843	0,754	0,940	0,908	0,940	0,908
Residual standard error	0,231	0,207	0,232	0,210	0,093	0,075	0,093	0,075
F-Statistic	40,2	24,0	48,3	27,9	788,4	500,1	1075,3	679,7
F numerator df	17	17	14	14	26	26	19	19
F denominator df	106	106	109	109	1287	1287	1294	1294

In venture capital fund regressions, firm type and fund type variables are both highly significant and may be treated as base cases describing average concentration in respective types of funds. Other variables then can be thought to describe variations to these base cases. It can be seen that stage focus dummies are significant for most of the stage types. This is natural as fund stage focus describes the fund's publicly expressed investment stage preference where as stage concentration metrics describe the observable realized stage concentration. Seed stage and early stage dummies are not as significant as other stage dummies. One possible explanation is that the seed and early stage funds primarily invest in companies at these stages. However, when some of the portfolio companies grow and prove successful, these early stage funds keep investing in them also in the subsequent financing rounds thus increasing their stage diversity. For funds investing primarily in later stage companies the portfolio companies generally represent the last stages of their evolution and hence there similar effect is not possible. Firm or fund location in venture capital hub does not have high significance impact on stage diversity as in case of industry regressions.

Like in case of industry diversification, all the macroeconomic control variables seem to be significant to venture capital fund concentration. Change in NASDAQ Composite Index returns, change in GDP, and level of interest rates all seem to decrease stage concentration. On the other hand, increases in R&D investment seem to increase stage concentration of venture capital funds. The signs of these respective coefficients are the same as in industry regressions. Also, the potential explanations are the same. However, the exact mechanics of how these control variables affect may need to be further discussed.

5.2.3 Time diversification, syndication, and number of portfolio companies

Table 14 shows the ordinary least squares (OLS) regression results with fund characteristics as independent variables and time diversification and syndication metrics as well as number of portfolio companies as dependent variables.

Table 14 Fund time diversification, syndication and portfolio size regression results

Ordinary least squares (OLS) regressions with capital weighted timing of investment rounds, capital weighted round number of investors, and number of portfolio companies as dependent variables. Regressions I and II are for buyout funds, and regressions III and IV are for venture capital funds. Specifications I and III use private equity firm type variable to describe fund affiliation and specifications II and IV use fund type variable to describe fund affiliation. Values in parentheses indicate t-statistic associated with estimate. Stars indicate significance level of estimate (* 99% significance ** 95% significance * 90% significance).**

	Dependent variables											
	Capital weighted round timing				Capital weighted number of round investors				Number of portfolio companies			
Independent variables	I	II	III	IV	I	II	III	IV	I	II	III	IV
Firm type: Private Equity Firm Investing Own Capital	-1,390		1,049 *		3,686 **		3,506 ***		-6,927		-39,769 ***	
	-(0,55)		(1,85)		(2,15)		(9,14)		-(0,39)		-(8,54)	
Firm type: Commercial Bank Affiliate or Subsidiary	-0,604		7,328 ***		4,200 **		4,242 ***		2,675		-10,573 *	
	-(0,20)		(9,75)		(2,04)		(8,35)		(0,13)		-(1,71)	
Firm type: Investment/Merchant Bank Investing Own or Client Funds	-1,220		1,305 *		3,044		3,740 ***		-10,862		-34,889 ***	
	-(0,44)		(1,68)		(1,62)		(7,11)		-(0,56)		-(5,46)	
Firm type: Affiliate/Subsidary of Oth, Financial, Instit,	-1,158		1,952 ***		3,808 *		3,549 ***		2,127		-40,303 ***	
	-(0,35)		(2,61)		(1,72)		(7,02)		(0,09)		-(6,56)	
Firm type: Investment Management Firm /Finance Consulting			0,445				3,546 ***				-17,123 *	
			(0,37)				(4,41)				-(1,75)	
Firm type: Corporate Venture Program			0,855				4,420 ***				-40,111 ***	
			(1,22)				(9,31)				-(6,95)	
Firm type: Venture Consulting Firm			2,387 ***				3,156 ***				-41,512 ***	
			(3,27)				(6,40)				-(6,93)	
Firm type: Private Equity Advisor or Fund of Fund Mgr	0,601		1,877 ***		2,804		3,503 ***		2,080		-37,098 ***	
	(0,23)		(2,80)		(1,57)		(7,74)		(0,11)		-(6,74)	
Firm type: Investment/Merchant Bank Subsidiary or Affiliate	-0,003		0,684		3,199		3,195 ***		-8,334		-38,671 ***	
	(0,00)		(1,04)		(1,60)		(7,16)		-(0,41)		-(7,13)	
Firm type: Corporate Subsidiary or Affiliate			5,107 **				0,094				-57,651 ***	
			(2,08)				(0,06)				-(2,86)	
Firm type: Insurance Firm Affiliate or Subsidiary			0,247				3,558 ***				5,218	
			(0,18)				(3,86)				(0,47)	
Fund type: PRIV		-1,230		0,895		3,427 **		3,399 ***		-5,859		-40,965 ***
		-(0,48)		(1,54)		(2,02)		(8,92)		-(0,35)		-(8,73)
Fund type: CORPVEN				1,613 **				4,157 ***				-36,900 ***
				(2,45)				(9,65)				-(6,95)
Fund type: FINCORP		-0,898		3,577 ***		3,598 **		3,232 ***		9,680		-35,468 ***
		-(0,33)		(5,43)		(2,00)		(7,51)		(0,54)		-(6,69)
Fund type: IBANK		-1,694		1,587 **		3,818 **		3,359 ***		1,131		-27,549 ***
		-(0,60)		(2,41)		(2,04)		(7,80)		(0,06)		-(5,20)
log(Firm capital under management)	0,274	0,233	0,031	0,154 ***	-0,552 ***	-0,523 ***	0,139 ***	0,148 ***	1,897	2,739 *	3,126 ***	3,793 ***
	(1,25)	(1,10)	(0,56)	(2,67)	-(3,75)	-(3,69)	(3,67)	(3,93)	(1,25)	(1,95)	(6,78)	(8,16)
Fund stage focus: Seed Stage			-0,008	0,057			-0,306	-0,309			-3,655	-3,156
			-(0,02)	(0,15)			-(1,22)	-(1,23)			-(1,20)	-(1,02)
Fund stage focus: Early Stage			-0,199	-0,161			0,138	0,119			-2,275 *	-1,797
			-(1,29)	-(1,01)			(1,33)	(1,14)			-(1,80)	-(1,39)
Fund stage focus: Expansion			0,042	0,032			-0,096	-0,098			-7,144 ***	-7,625 ***
			(0,14)	(0,10)			-(0,47)	-(0,48)			-(2,88)	-(3,03)
Fund stage focus: Later Stage			-0,375	-0,258			-0,448 ***	-0,388 **			-5,145 **	-4,595 **
			-(1,54)	-(1,03)			-(2,73)	-(2,38)			-(2,58)	-(2,29)
Is first time fund?	0,534	0,147	1,354 ***	1,161 ***	0,277	0,496	-0,227 *	-0,217	-0,654	-3,842	6,671 ***	6,555 ***
	(0,65)	(0,18)	(6,98)	(5,77)	(0,50)	(0,92)	-(1,73)	-(1,65)	-(0,12)	-(0,72)	(4,19)	(4,04)
Fund sequence number	-0,099	-0,107	-0,082 ***	-0,047 **	0,099 *	0,104 *	0,024	0,024 *	-0,312	-0,325	-0,195	-0,181
	-(1,20)	-(1,30)	-(3,87)	-(2,15)	(1,78)	(1,92)	(1,64)	(1,67)	-(0,54)	-(0,60)	-(1,12)	-(1,04)
log(Fund size)	-0,291	-0,273	-0,083	-0,182 **	0,171	0,155	-0,299 ***	-0,294 ***	-0,650	-1,598	5,167 ***	4,947 ***
	-(1,08)	-(1,00)	-(0,98)	-(2,11)	(0,94)	(0,85)	-(5,24)	-(5,19)	-(0,35)	-(0,89)	(7,46)	(7,10)
log(Firm age at fund inception + 1)	0,468	0,380	0,350 ***	0,211 **	0,194	0,241	-0,064	-0,062	1,897	0,595	1,104 *	0,728
	(1,44)	(1,14)	(4,35)	(2,55)	(0,89)	(1,09)	-(1,17)	-(1,15)	(0,85)	(0,27)	(1,67)	(1,10)
Is fund or firm from PE hub?	-0,255	0,043	0,005	-0,077	0,181	0,072	0,614 ***	0,609 ***	-6,187 *	-3,394	0,453	-1,041
	-(0,48)	(0,08)	(0,03)	-(0,53)	(0,51)	(0,21)	(6,41)	(6,37)	-(1,69)	-(0,98)	(0,39)	-(0,88)
Committed capital delta	-0,851	-0,936	0,304 ***	0,322 ***	-0,690 *	-0,595	0,079	0,084	3,213	3,755	2,418 ***	2,329 ***
	-(1,43)	-(1,58)	(3,94)	(4,03)	-(1,73)	-(1,52)	(1,51)	(1,60)	(0,78)	(0,96)	(3,82)	(3,62)
NASDAQ Composite delta	0,340	0,096	0,315	0,266	-0,241	-0,210	-0,592 ***	-0,544 ***	6,978	1,679	4,497 *	4,740 *
	(0,26)	(0,08)	(1,01)	(0,82)	-(0,28)	-(0,25)	-(2,81)	-(2,58)	(0,78)	(0,20)	(1,75)	(1,83)
R&D investment delta	-20,666	-20,911 *	-22,994 ***	-23,210 ***	4,565	5,591	14,735 ***	14,170 ***	-158,879 *	-122,753	-55,836 **	-63,004 **
	-(1,61)	-(1,66)	-(7,24)	-(7,08)	(0,53)	(0,67)	(6,87)	(6,61)	-(1,79)	-(1,48)	-(2,14)	-(2,39)
GDP delta	15,992	17,511	15,332 ***	17,873 ***	-1,407	-4,672	-6,080 **	-5,068 *	-125,772	-138,356	58,986 *	75,394 **
	(0,67)	(0,75)	(3,58)	(4,06)	-(0,09)	-(0,30)	-(2,10)	-(1,76)	-(0,77)	-(0,90)	(1,67)	(2,13)
Bond yield	0,367 **	0,415 **	0,213 ***	0,195 ***	0,177	0,176	0,157 ***	0,155 ***	3,178 **	3,050 ***	2,298 ***	2,124 ***
	(2,08)	(2,42)	(5,87)	(5,19)	(1,49)	(1,54)	(6,39)	(6,33)	(2,61)	(2,69)	(7,71)	(7,02)
Multiple R-squared	0,633	0,614	0,744	0,724	0,771	0,766	0,912	0,911	0,621	0,639	0,715	0,705
Adjusted R-squared	0,574	0,565	0,739	0,720	0,735	0,736	0,910	0,910	0,561	0,592	0,709	0,700
Residual standard error	2,66	2,69	2,39	2,47	1,79	1,79	1,61	1,62	18,38	17,71	19,60	19,90
F-Statistic	10,8	12,4	143,9	178,8	21,0	25,5	511,6	697,3	10,2	13,8	124,2	162,6
F numerator df	17	14	26	19	17	14	26	19	17	14	26	19
F denominator df	106	109	1287	1294	106	109	1287	1294	106	109	1287	1294

The results are similar to previous ones in that in buyout fund regressions there are far fewer significant coefficients. Again, it seems that fund type and firm type do not have significant effect on the dependent variables except in specification II of capital weighted round number of

investors. Regarding time diversification, the results show that higher debt yields are associated with increased capital weighted round timings. This is natural as the profitability of certain types of buyout transactions such as leveraged buyouts (LBO) is highly dependent of cost of debt capital. With higher cost of debt, there are fewer attractive deals available for buyout fund managers and it takes longer to find suitable deals to fully invest the fund capital. Regarding capital weighted round number of investors, larger buyout firms tend to co-invest less than smaller buyout firms. Buyout fund size on the other hand is not significant in regression, which is interesting. In regressions with number of portfolio companies as dependent variable, debt yield is also significant, which is not surprising given the tendency of buyout funds to lever up their investments.

For venture capital funds, there are again many significant variables. Fund type is in most cases a significant explainer of time diversification, syndication, and number of portfolio companies. Firm type is also significant in most cases but there are several cases where it is not.

For first time funds it takes longer to invest the fund capital. Also, funds with higher sequence numbers invest their capital faster than funds with lower sequence numbers. Longer time to invest can be expected because follow-on fund managers may be better networked and have better access to deal flow than first time fund managers. The results show that the older the venture capital firm at fund inception, the longer it takes to invest the fund. This is somewhat odd since it could be hypothesized that more established could have better access to deal flow than less established ones.

Larger venture capital firms tend to syndicate more but on the other hand, larger venture capital funds tend to syndicate less. This seems little bit controversial. One potential explanation could be that larger firms operate smaller funds; however, data does not support this explanation. Funds or funds of firms that operate in venture capital hub states tend to co-invest more and later stage funds tend to co-invest less. Increased tendency to syndicate of venture capital hub associated funds can be explained by the extensive size of venture capital networks on those states. Syndication can be seen a response to uncertainties regarding investment target. Co-investors can either provide complementary value adding management resources or alternatively provide a valuable second opinion regarding the quality of investment target. Decreased tendency of later

stage funds to syndicate can be explained by lower degree of uncertainty that is associated with the more mature stage of target companies.

Larger firms and larger funds tend to have more firms in their portfolios than smaller firms and smaller funds. This is natural as ceteris paribus, the larger the fund the more companies in can invest in. Also natural is that expansion and later stage funds tend to have less portfolio companies than seed and early stage funds. This is because later stage companies tend to be larger and ceteris paribus the larger the size of portfolio companies the fewer companies the fund can invest in. First time funds tend to have more companies in their portfolios than follow-on funds. This shows that first time fund managers do not seem to have trouble finding investment targets despite potentially less restricted access to deal flow. No conclusions about the quality of deals can be made.

Like in other regressions, control variables change in committed capital, change in NASDAQ Composite, change in R&D, change in GDP, and bond yields are significant for most venture capital regressions.

5.2.4 Multivariate regression summary

Table 15 summarizes all regression results to present a more complete view of the overall results. This section outlines briefly the main results and tests the regression results against hypotheses stated earlier.

First, the regression data does not without qualification support the hypothesis that there would be significant difference in first time and follow-on fund concentrations or the hypothesis that first time funds would be more concentrated. There is no significant difference in industry and stage concentrations, but on the other hand, first time funds tend to contain more companies. The data shows that first time funds take longer time to invest.

Second, the regression data does not support the hypothesis that there would be significant diversification differences between funds with higher and lower sequence numbers. Funds with high sequence numbers, however, seem to get invested faster than funds with low sequence numbers. Firm age at fund inception is another proxy for fund manager experience and reputation. For this variable, the data shows diversificatory effect in terms of portfolio company

industries. However, older firms also tend to take longer time to invest fund which is somewhat surprising.

Table 15 Summary of regression results

Summary of regression results shown in previous chapters. The table shows significance of each independent variable for each dependent variable that was studied. Variables under Industry and Stage columns are Herfindahl-Hirschman concentration indices calculated at each classification hierarchy level. TDIV denotes capital weighted financing round timings, SND denotes capital weighted round number of investors, and NCOMP denotes number of portfolio companies. The coding is as follows: +++ positive at 99% level, ++ positive at 95% level, + positive at 90% level, --- negative at 99% level, -- negative at 95% level, - negative at 90% level.

Panel 1: Venture capital funds

	Industry			Stage				
	HHI1	HHI4	HHI6	HHI1	HHI3	TDIV	SND	NCOMP
Fund stage focus: Seed Stage				+	+++			
Fund stage focus: Early Stage	+++	+++		+++	+			
Fund stage focus: Expansion			+++	+++	+++			
Fund stage focus: Later Stage		++	+++	+++	+++		---	--
log(Firm capital under management)	+		-	---			+++	+++
Is first time fund?						+++		+++
Fund sequence number	-		+			---		
log(Fund size)		---	---	-	---		---	+++
log(Firm age at fund inception + 1)	--	---	---			+++		
Is fund or firm from PE hub?	+++		--	+			+++	
Committed capital delta	--	---	-	--	--	+++		+++
NASDAQ Composite delta	---			---	--		---	+
R&D investment delta	+++			+++	++	---	+++	--
GDP delta	---			---	-	+++	--	++
Bond yield	---	---	---	---	---	+++	+++	+++

Panel 2: Buyout funds

	Industry			Stage				
	HHI1	HHI4	HHI6	HHI1	HHI3	TDIV	SND	NCOMP
log(Firm capital under management)							---	
Is first time fund?								
Fund sequence number							+	
log(Fund size)				++				
log(Firm age at fund inception + 1)								
Is fund or firm from PE hub?								
Committed capital delta								
NASDAQ Composite delta								
R&D investment delta								
GDP delta		++	+					
Bond yield						++		+++

Third, the data shows evidence for the hypothesis that increased capital commitments lead to increased deal competition for venture capital funds, and lead to reduced fund concentration. Additionally, the data shows that increased capital supply tends to increase time needed to invest fund and increase the number of companies the fund invests in. From the demand side, the data

also shows evidence for the hypothesis that increased venture capital demand in form of R&D investment will act the opposite way. In addition however, the data shows that increased R&D investment also increases the tendency of funds to syndicate. This is in line with the view that new startup-stage growth business is inherently more risky and syndication offers a valuable second opinion regarding investment quality.

Finally, Larger venture capital funds tend to be more diversified in terms of industries and stages, and have more companies in their portfolios, which supports the hypothesis made regarding fund size. In addition larger size funds tend to syndicate less which supports the risk sharing motive for syndication. For buyout funds, data does not show this effect.

6 Summary and conclusions

In this study it was examined what are the main observable determinants of private equity fund diversification. These determinants were studied for both venture capital funds and buyout funds. Different types of diversification studied were: diversification across portfolio company industries, diversification across portfolio company stages, time diversification of financing rounds, number of portfolio companies. Also, related issue of tendency of funds to syndicate investments was studied. Hierarchical industry and stage classifications were studied at multiple levels. The data set consisted of over 70000 financing rounds of U.S. based private equity funds from years 1965 to 2007. With all filtering criteria applied, over 1500 distinct remained in the data set.

The following sections summarize the key findings considering both the results of univariate analysis and multivariate regression analysis considering all findings together and comparing the results to the hypotheses formulated in chapter 3.

Venture capital fund size

Regarding venture capital funds, the results show that the larger the firm capital under management, the more stage diversified the firm's funds tend to be. Funds of capital rich firms also tend to syndicate more and have more companies in their portfolios. Negative effect on stage concentration alone could be caused by possible higher number of balanced stage funds managed by larger venture capital firms. Increased tendency to syndicate and larger number of portfolio companies could be explained by better access to deal flow and more extensive contact networks from which suitable syndicate partners can be found.

Fund size has significant diversificatory effects, as predicted by respective hypothesis. Funds with larger committed capital amounts tend to be less concentrated with respect to industries and to some degree also with financing stages of their portfolio companies. These funds also tend to syndicate less and have more companies in their portfolios. Many of these results are not surprising as increased fund size makes it possible to invest in more companies and investing more companies makes it more likely that these companies represent different industrial classifications and stages. Increased size makes the fund less dependent on syndication based on purely financial motives.

Venture capital fund manager experience

The results show that for first time funds it takes longer to invest the fund and that first time funds also tend to have more companies in their portfolios. Fund sequence number does not seem to have significant effect on industry or stage diversification. However, the higher the fund sequence number, the less time it takes to invest the fund.

These results suggest that funds of more established firms tend to have better access to deal flow, which makes it easier for them to find investment targets thus reducing the time it takes to invest fund. The results do not support the hypothesis that first time funds would have an incentive to outperform the market. Rather, the results give support to null hypothesis that first time funds are better off if they rather try to avoid catastrophic failures and diversify. The first time fund diversifying effect is not seen in industries or stages but rather in number of portfolio companies. Taking into account that venture capital investments generally imply very high firm specific risk and lesser amount of industry specific risk, the greatest diversification benefits may be obtained by simply investing in more companies. Investing in more companies allows the fund manager to keep focus in industry and stage segments where greatest benefits from reduction of agency costs through fund manager experience and expertise can be realized. Considering these aspects, the findings make sense.

The age of venture capital firm at fund inception has significant effects on fund industry concentration and fund investment time. The older the venture firm, the more industrially diversified the funds tend to be and the more time it takes to invest the fund. This is surprising as venture firm age can be though as a proxy variable for firm experience and reputation. It would be expected that more experienced and reputable fund managers would be able to invest their funds faster. On the other hand, it can be that these funds have stricter investment criteria than other funds, which has effect in fund investment time.

Venture capital fund location

Funds and firms that operate in U.S. private equity hub states California, New York, and Massachusetts tend to be more industrially concentrated at the highest level of industry classification. In addition, these funds also tend to syndicate more than other funds. These results

could be due to the fact that some locations such as the Silicon Valley of California are heavily concentrated on specific industries, mainly information and communication technology, which shows in the results. Also, the high number of venture capital companies concentrated on the three private equity hub states increases the scope of venture capitalist networks and provides favorable preconditions for syndication between venture capital funds.

Supply and demand of venture capital

Increased amount of committed private equity capital at fund vintage year tends to increase fund diversification with respect to portfolio company industries and stages. Increased capital commitments also tend to make the time required to invest fund longer and increase the number of companies in fund portfolios. The results are congruent with the hypothesis that increased capital flows into venture capital funds tend to increase deal competition and force the fund managers to find investment targets outside their preferred investment scope. The fact that number of portfolio companies also increases with amount of increased committed capital may suggest that the deal sizes do not grow in the proportion of increased capital inflows and that the funds may in fact have to invest in smaller deals than they would otherwise prefer to.

Increased research and development investments at fund vintage year tend to increase fund industry concentration in the highest classification level and also increase the stage concentration. Increased research and development investments also tend to decrease the time required to invest fund, increase the tendency to syndicate investments, and to decrease number of fund portfolio companies. These effects are largely inverse to the effects observed regarding capital committed in funds except that committed capital variable did not have effect on tendency of funds to syndicate. These results support the view that R&D investment creates demand for venture capital and also that these investments generate new business that may not be previously familiar to venture capitalists. Because of novelty of the new business opportunities, funds may tend to syndicate more. Syndication allows the fund managers to have a valuable second opinion in their decision to invest and also allows the fund managers to acquire complementary management resources such as knowledge and expertise that increases the probability of investment success.

Macroeconomic variables and venture capital fund diversity

Level of Baa-grade corporate bond yields is significant at 99% level for all dependent variables. High bond yield tends to increase industry and stage diversity, increase time needed to invest fund, increase tendency to syndicate, and increase number of portfolio companies. Bond yields can be decomposed into risk-free interest rate and risk premium components and are affected by many different factors, business cycles and general macroeconomic conditions among the most important ones. Venture capital funds tend not to use significant amounts of debt in their investments and as such, cost of debt should not significantly affect the profitability of venture capital deals. I do not have a theory to explain these concentration effects but further research in the subject could prove beneficial in uncovering this relation.

Like corporate debt yields, change in general equity market valuation measured with change in NASDAQ Composite, and change in GDP growth at vintage year also have significant effects on many concentration metrics but these effects are not as pronounced as effect in case of debt yields.

Diversification differences between venture capital fund types

Univariate tests show that venture capital funds associated with financial corporations and investment banks tend to be more diversified than private funds and corporate venture funds in first and fourth industrial classification level. Also, corporate venture funds tend to be more concentrated than private funds in industrial classification level four and six. This supports the hypothesis that corporate venture funds tend to concentrate on industries that are related to the main business the corporation operates in. Corporate venture funds also tend to be more concentrated in terms of financing stages than other types of funds.

Results concerning buyout-funds

The study shows that diversification of venture capital funds is much better explained by variables used in the study than diversification of buyout funds. This is not so surprising as such but rather how few significant observations were found. One reason could be that the number of venture capital funds is far higher than number of buyout funds in the sample, which could in statistical sense reduce the explanatory power of tests applied. On the other hand, it could be

argued that buyout business should be more stable and therefore less sensitive to many of the factors that venture capital funds are sensitive to.

For buyout funds the results show that the larger the size of private equity firm, the less the fund tends to syndicate. Also, the larger the size of fund, the more concentrated the fund tends to be to specific financing stages. Both results are natural. In buyout business where investment targets generally are mature companies, the primary motive to syndicate tends not be acquisition of complementary management resources or reduction of uncertainty regarding investment quality but rather gathering larger amounts of capital required to buy larger targets. Therefore, it can be expected that funds of larger firms need not so readily co-invest with funds of other firms in order to gather the required amount of capital. Also, larger funds tend to concentrate on larger deals which tend to involve larger and more mature companies. Large portion of mature companies in fund portfolio increases the stage concentration around mature stage companies.

Buyout funds raised when debt yields are high, tend to invest the fund slower and have more companies in their portfolios than funds raised when yields are low. Since cost and availability of debt capital is a significant determinant of leveraged buyout (LBO) deal profitability, the longer investment time can be explained by the fact that there are fewer profitable investment opportunities when cost of debt is high and it takes more time to find profitable investment targets to fully invest the fund.

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